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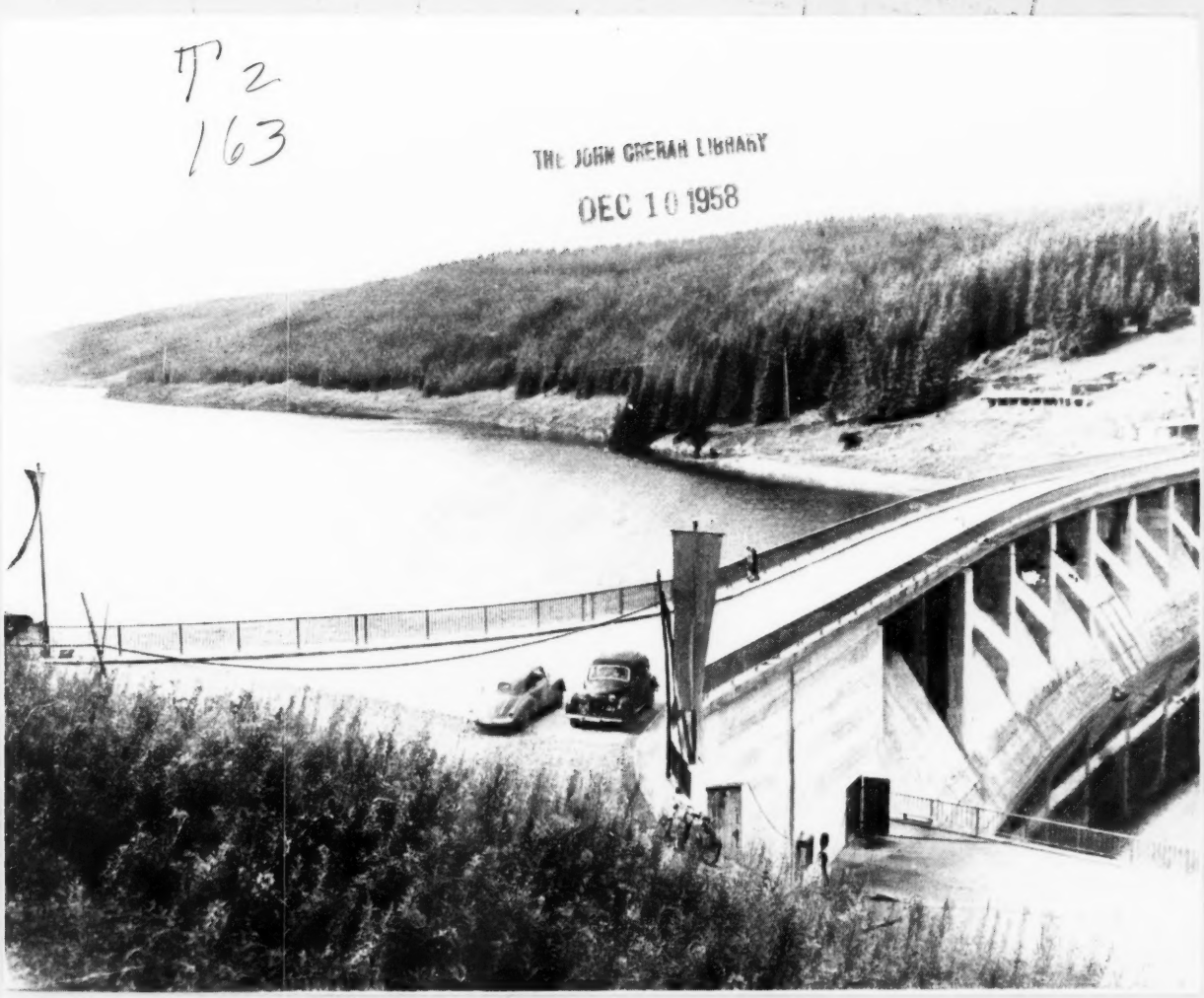

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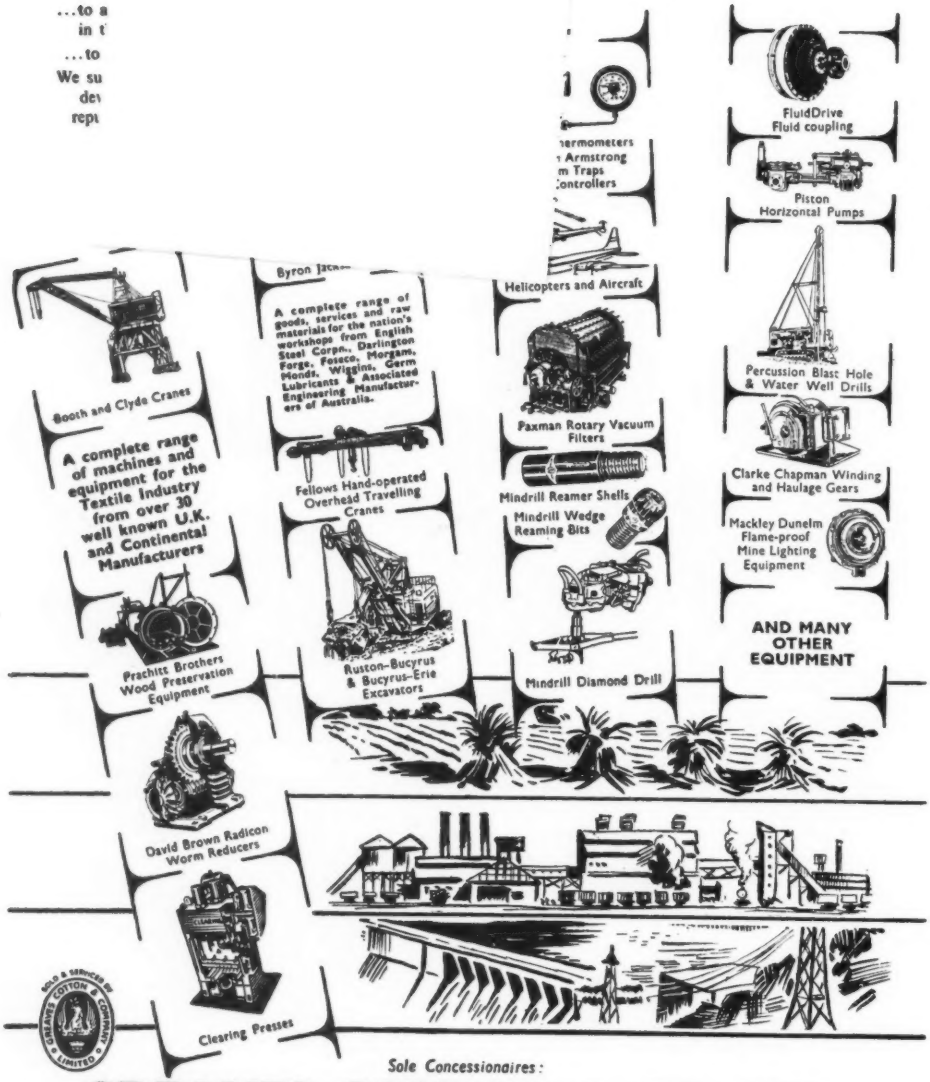
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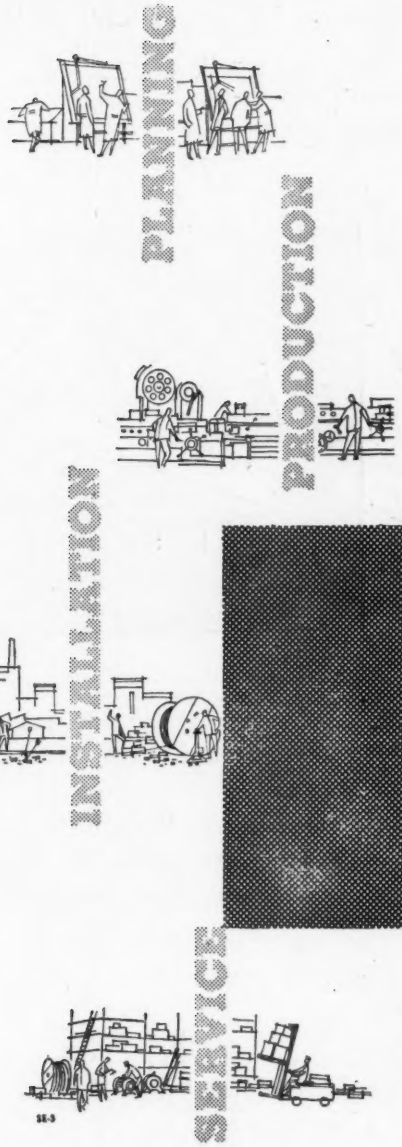

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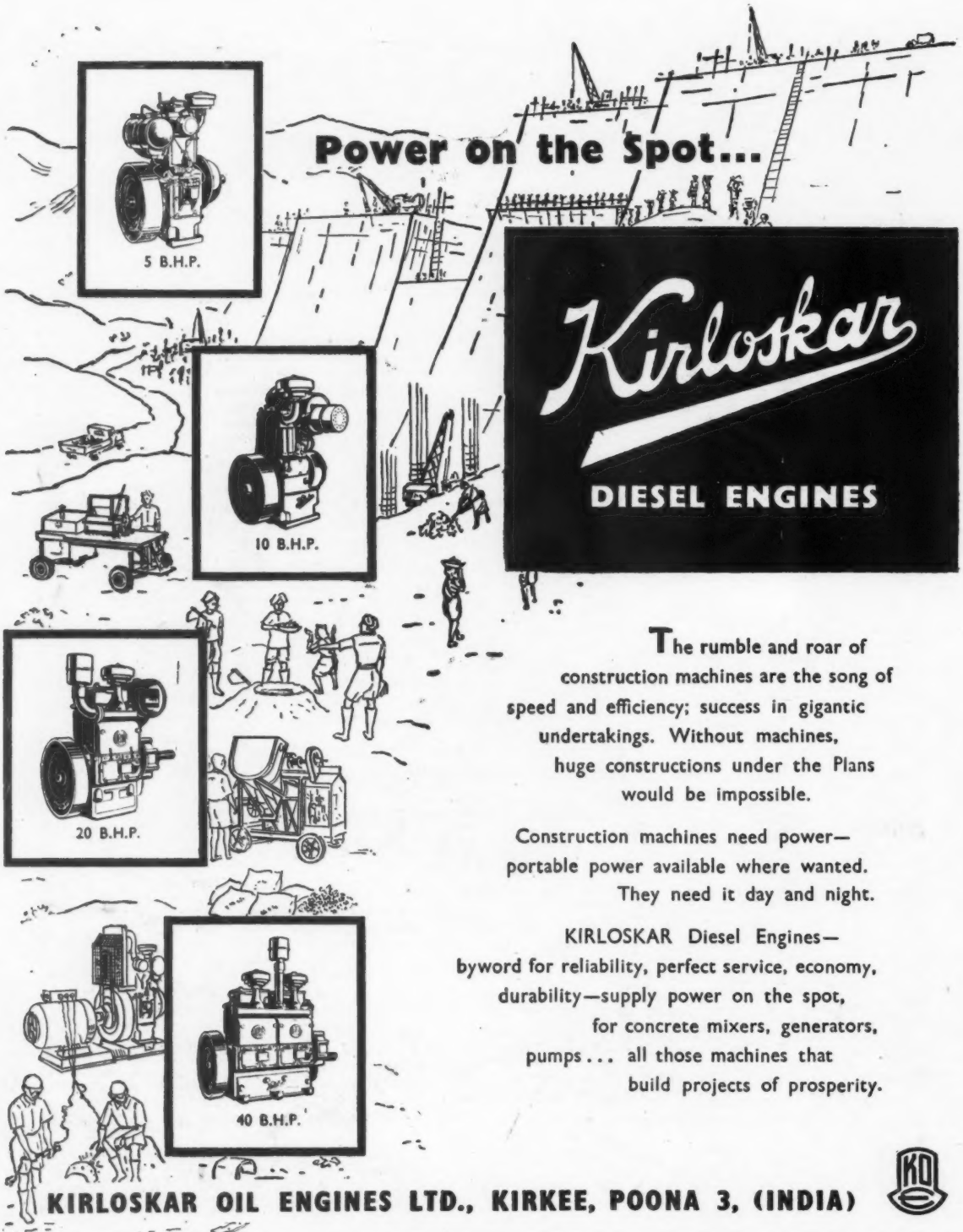

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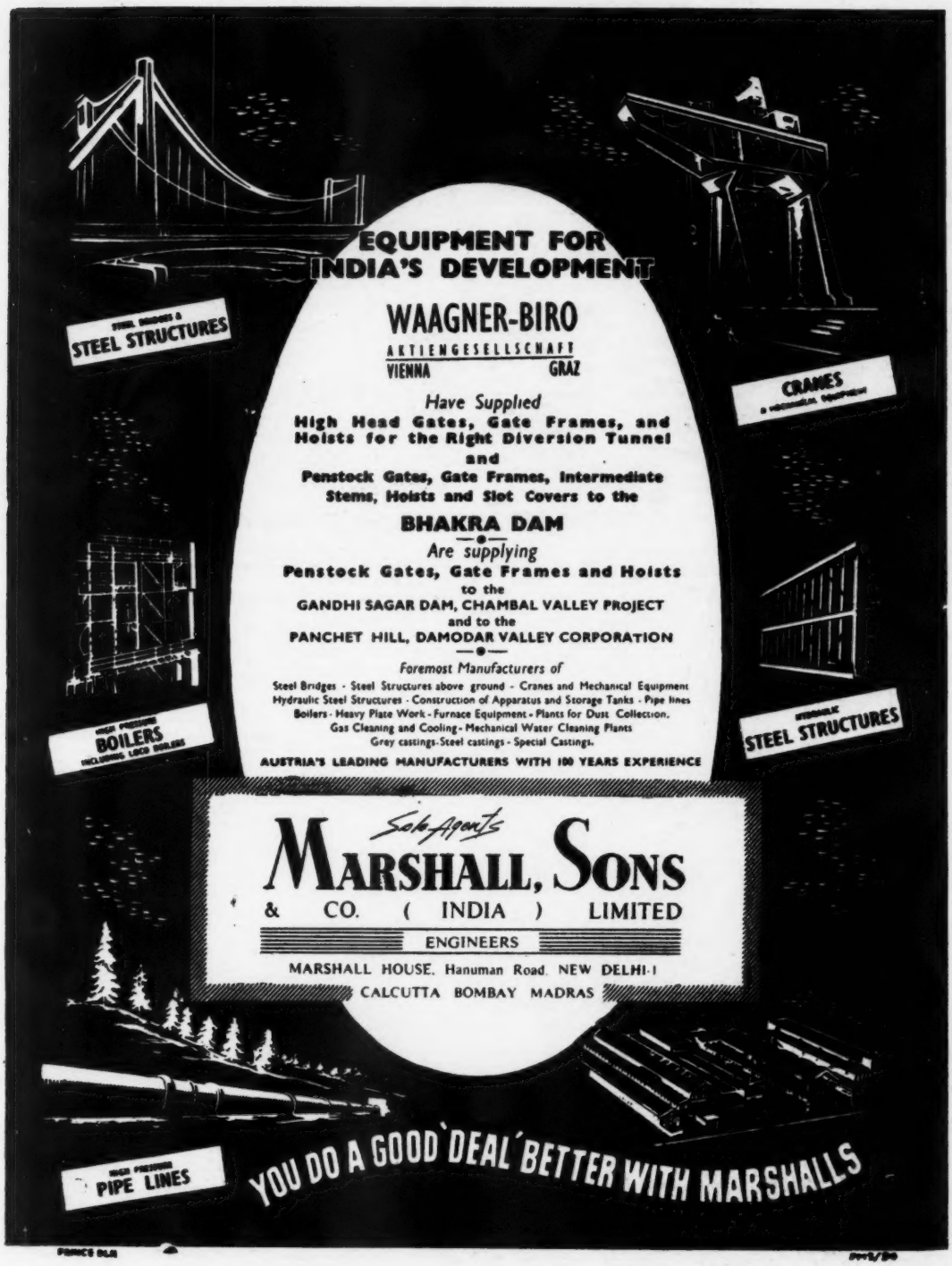
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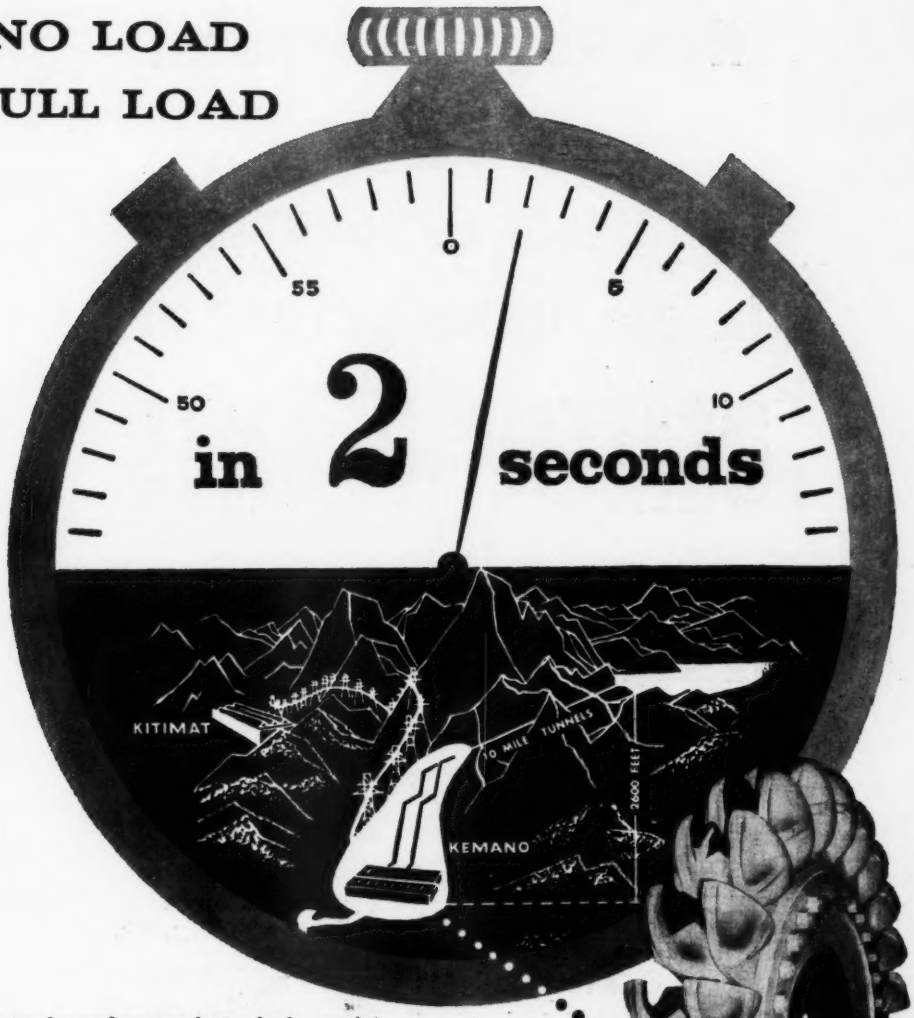

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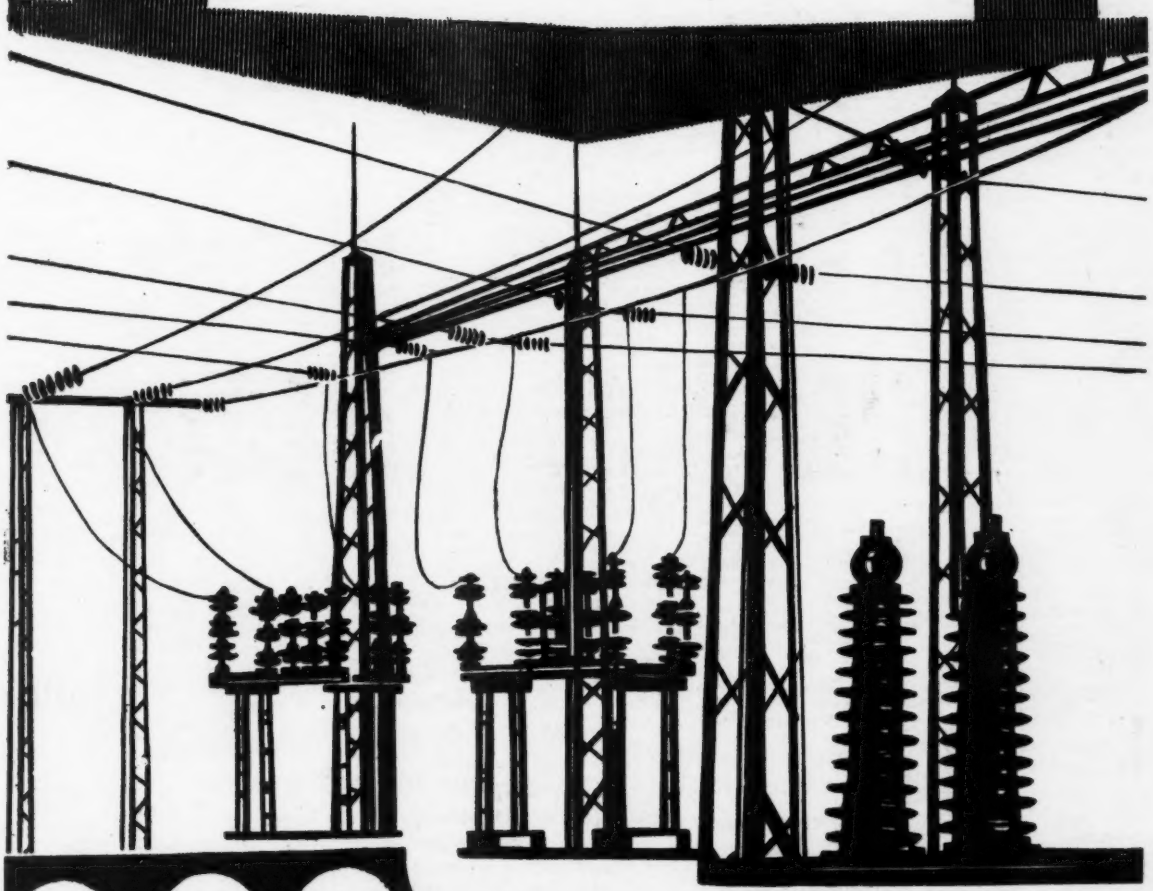

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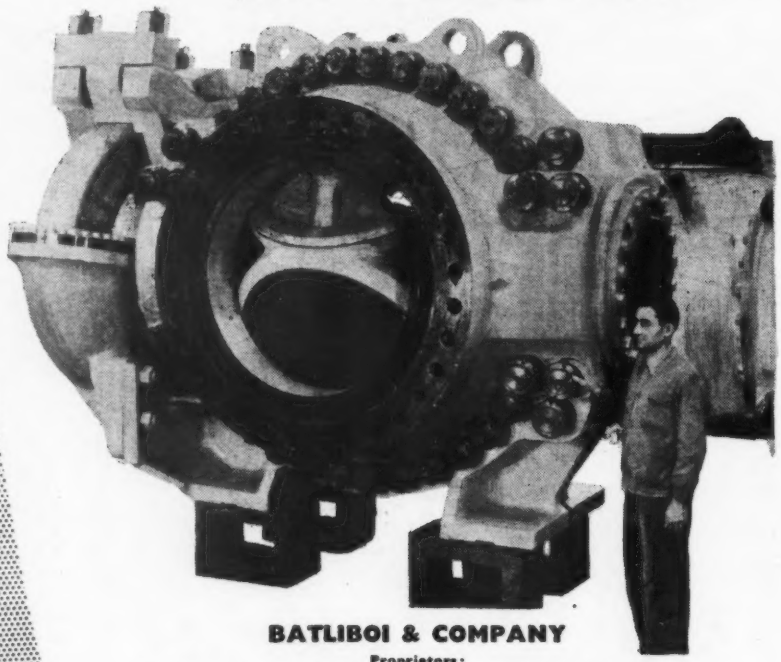

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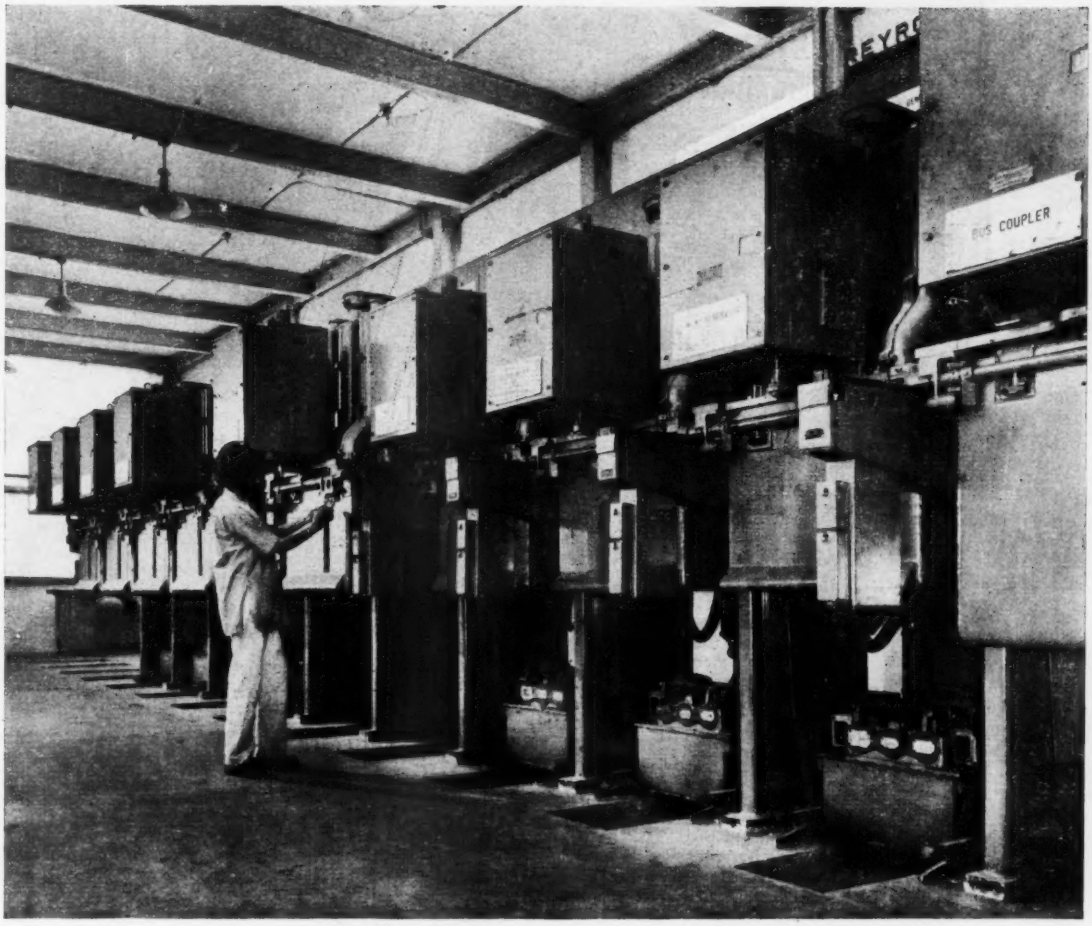

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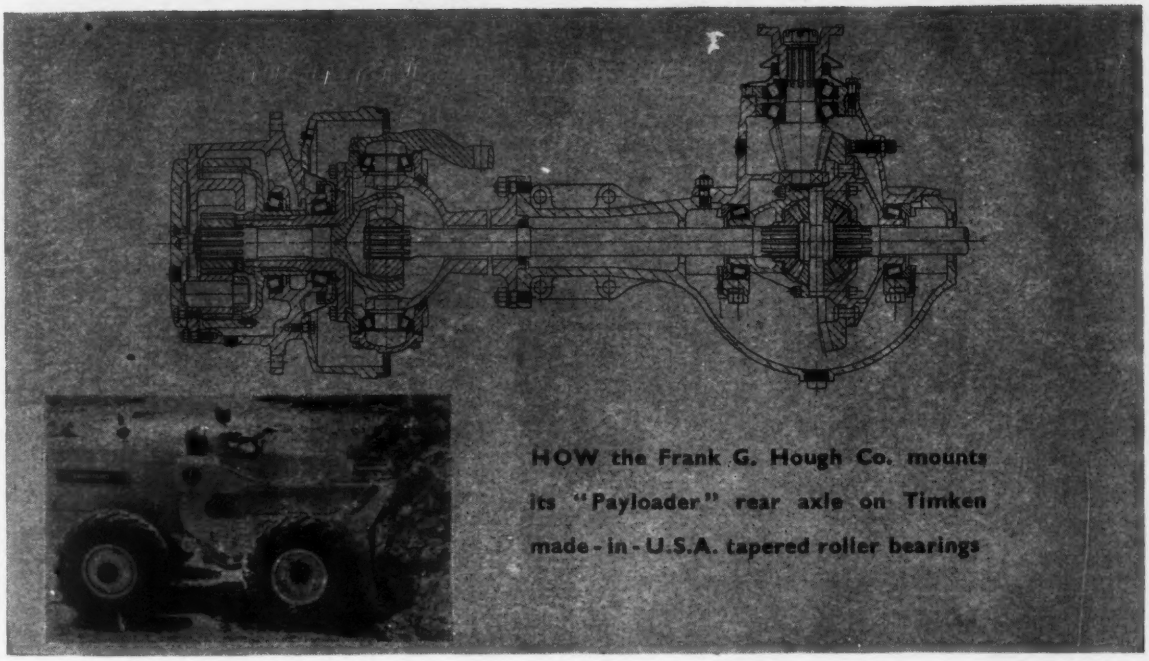

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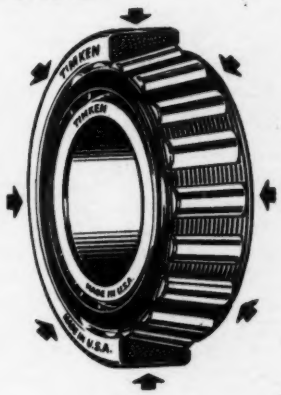

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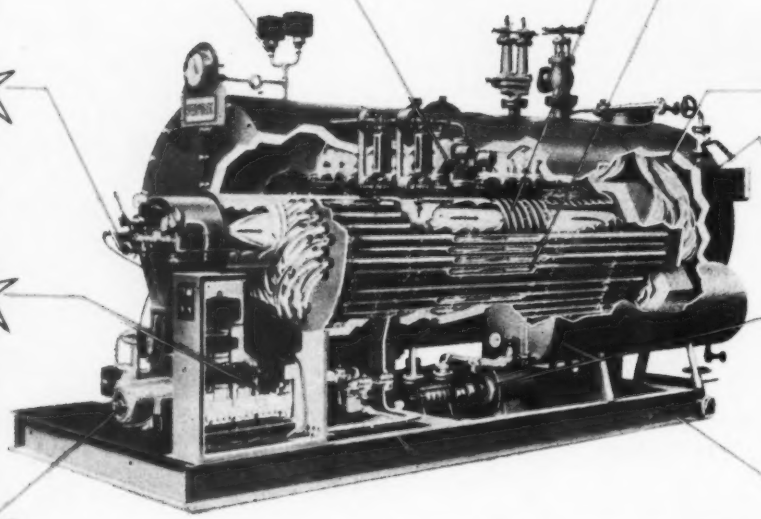

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Editor : K. K. Sinha — P. K. Menon : Mg. Editor

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EVEREST

Modern Trends in Hydro-Electric Power Field

By Dr. W. DIESENDORF

Summary : The most striking feature of recent hydro-electric projects is that they tend to be comprehensive in various aspects. They may embrace one or more rivers or river systems, and may serve many national purposes in addition to power generation. In all cases, however, they are carefully co-ordinated with other available sources of electric power, such as coal-fired or nuclear power stations. Of particular interest to the power engineer is, in this connection, the emphasis placed on peak power generation, either by natural or artificial (pumped) storage schemes. Mention is also made of the progress in power plant and equipment as influenced by the above tendencies and by the search for more economical or novel solutions.

Introduction

Water power is a subject of great fascination to engineers. There are many reasons for this. Hydro-electric schemes are of great varitety, which is due to the different natural conditions into which they have to be fitted, but to some extent also to the diversity of man-made circumstances of power demand and utilisation. This variety always lends fresh interest to a branch of engineering which has its roots in antiquity ; it also calls for stimulating co-operation between the practitioners of the major disciplines of engineering and of many auxiliary branches. Finally, once developed, water power provides a practically inexhaustible supply of energy.

A brief survey of present trends has been prepared from the point of view of the electrical power engineer using as a basis selected reports from the 1956 World Power Conference (Ref. 1), other recent literature and personal observation.

Although Australia derives 83 per cent of electrical energy from the combustion of fuels of all kinds, mainly coal, and only 17 per cent from water power, much of it in Tasmania, there are now on the mainland some large hydro-electric projects under construction or partly completed. These developments have stimulated interest in water power and caused discussion regarding its merits. It is, therefore, advantageous to review trends in other parts of the world ; although it is rarely possible to transfer practices from one country to another without adaptation to local conditions, some general principles may be discernible and prove useful for further study.

Classification of Trends

In attempting a board classification of the observed trends, as a guide to further detailed discussion, the following three can be readily defined.

First Trend

Hydro-electric schemes tend to become more comprehensive. This trend has three aspects :

(*a*) Modern schemes are comprehensive in a physical sense. In the past it was usual to select the scheme that was cheapest and most conveniently situated to the load centres and develop it regardless of any prejudice to the economical future development of adjacent sites. Many old schemes are now being by-passed and have thus become obsclescent prematurely. Plans that have been drawn up recently embrace one or more rivers or river systems, so as to develop the whole available head to the limit of economy, although the actual construction may be spread over a long period. As a corollary, modern schemes are often planned to disregard national boundaries with the aim of achieving a better overall solution than would otherwise be possible.

(*b*) The second aspect of this trend is that schemes are comprehensive in a functional sense. Many power schemes at present proposed serve simultaneously a number of other important national functions such as irrigation, flood prevention, navigation, municipal and industrial water supply, waste disposal, preservation of fish and wild life, forestry and recreation. Quite often a power scheme which is only of marginal economy becomes attractive if part of its cost is equitably allocated to other national benefits associated with it.

(c) The third aspect is that schemes are designed for optimum co-ordination with other sources of electric power which is again "comprehensiveness" in a different dimension.

The problem is usually how best to combine thermal power, run-of-river and storage hydro power, and lately also nuclear power, in order to match the characteristics of the electrical load. Its solution depends on the relative availability and characteristics of the different kinds of energy. In a country with ample and cheap water power, thermal stations are normally used for peak generation and so conserve expensive fuel at times of abnormally low water flow, for supplementing and "firming" the hydro-electric deficiency. In countries with little water power, it is used to best advantage for peak load generation provided adequate storage can be created. However, even countries which at present derive their energy requirements from bountiful water power supplies can already foresee the complete development of these resources within the next one to two decades ; they are therefore faced with an impending transformation to a mixed generation system. It seems therefore that, ultimately, most countries will have preponderantly thermal systems which will include nuclear power. In all cases the economic necessity for co-ordination of the various sources of energy in the optimum manner is one of the reasons for large interconnected grids and power pools (there are of course also other reasons such as reduction of installed capacity due to diversity of demand and smaller reserve) ; a tendency which is assisted by the increase of transmission voltages and the cheapening of bulk transmission.

The same economic incentive acts in favour of the co-ordination of the different kinds of energy resources on an international scale.

Second Trend

As already mentioned, water power resources of hydraulically well-developed countries are approaching full development; this applies even to countries like Canada, France, Italy, Sweden and Switzerland and is due to the universally rapid rise in the consumption of electrical energy. Accordingly, there is a tendency to develop hydro-electric resources which, not long ago, were considered as uneconomical ; they include water power in locations remote from the load centres and novel kinds of energy such as the power of the tides. It even leads people to think of schemes which seem rather fantastic, such as the shutting off of large estuaries in tropical areas by dams and relying on evaporation to establish a permanent difference in level between the ocean and the estuary to provide the head for the turbines. One such scheme is in operation on the West Cost of Africa.

Third Trend

Lastly, reference should be made to the inherent trend in engineering which leads to continual improvements in the design of the components of hydro-electric schemes with a view to improved economy, performance and reliability. Another aspect of technical progress is the development of novel designs of hydro-electric machinery needed for novel solutions, such as large pumps and reversible pump-turbines for high and medium head for pumped storage schemes, and also for very low heads as required for tidal power stations.

Comprehensive Development in a Physical Sense

Once electricity supply had emerged from the era of catering for restricted local needs, the advantages of planning the development of a river system from its source to its confluence with the main stream, or the ocean, became very obvious. In the lower course of the rivers, where only low heads can be developed, the spacing of the successive stages requires careful thought in order to avoid inundating valuable agricultural land, highways, railroads and human habitations. In the upper reaches of the rivers it is often possible to increase the catchment area of a project by diversion tunnels, aqueducts and racelines, thus achieving a more concentrated and, therefore, more economical development. By diverting rivers through tunnels into neighbouring valleys a greater head can sometimes be developed over a shorter distance, or a junction with another river can be achieved for the purpose of combined development, or simply a better or more accessible site for the power station may be secured. To achieve the aim of greater physical extension, engineers are no longer bound to rely on gravity alone to make the water flow where they want it to, but they install pumps if necessary ; apart from affording greater flexibility in design this may be very profitable in terms of energy if by pumping over a small head a much larger head is gained for generation. Some of the schemes described later will illustrate these various features.

In many countries a careful inventory of potential water power (Ref. 2) is being compiled as a basis for comprehensive plans of development.

Under-developed countries, which are latecomers to the power field, consider planning and development on a large scale as the most appropriate and most modern technique to be adopted as a matter of course. It may be of interest to mention some of the less known schemes, some of which are staggering because of their magnitude.

In China (Ref. 3) the Yangtze River System has a planned power potential of 144,000 MW, the Hwang Ho System 24,000 MW, both based on flow for 50 per cent of time. The development of these two rivers is planned with power station capacities of the order of 1,000 MW and more. A start is to be made this year on the 1,000-MW Station Sanmen Gorge on the Hawang Ho.

In India (Ref. 4) there are a number of large projects under construction which are the first fruits of comprehensive planning (Damodar Valley—144 MW; Bhakra-Nangal—544 MW, and others).

As a curiosity, mention should be made of one of the most concentrated of potential developments in the world (Ref. 3) ; it is on the Brahmaputra River near the India-China border where a tunnel of only 30 miles in length, cutting off a bend of the river, would permit the utilization of a head of 8,000 ft. and a flow of 70,000 cusecs, resulting in a power of 50,000 MW.

The Suddel Aali project of Upper Egypt (Ref. 5) would increase the cultivated area of Egypt by 50 per cent by virtue of a reservoir storing 106 million acre feet of Nile water, and stimulate industrial development in the Delta, 500 miles distant.

National boundaries used to be considered an obstacle to the rational and comprehensive development of river systems. This is no longer so. The less difficult case, legally, is the one where a stretch of river forms a boundary between two countries which enter into an agreement regarding the construction of power stations and the sharing of the cost, the power and the energy output of the scheme, not forgetting the splitting of the contracts for the supply of equipment.

In the St. Lawrance Seaway Project (Ref. 6) at present under construction, the power house stretches almost across the river with Canadian and American sections conveniently located on either side of the border which runs along the middle of the stream. Each section contains 16 generators of 62.5 MVA rating.

In smaller power stations such as those on the Rivers Inn, Danube and Rhine, which have only a few turbine-generator sets each, it is a more difficult problem how to achieve reasonable uniformity of equipment without detriment to the manufacturing interests of the two countries concerned. Sometimes agreement is reached between the manufacturers on the leading dimensions; on other occasions an even neater solution has been adopted, one firm making all the stators of the generators, and another firm, on the other side of the border, all the rotors.

The second case where a river flows across the boundary from one country into another is much harder to handle from a legal point of view, seeing that no international law exists as a guide in the complex situations that arise. Any development on the upstream side of the border may seriously influence conditions downstream of the border. For example, the flow may be reduced by diversion ; on the other hand it may be improved by regulation. A case at present causing difficult negotiations is that of the Columbia River (Ref. 7) which has its source in Canada and crosses into the United States, and the Kootenay River which has its origin very close to that of the Columbia River but flows in the opposite direction, crosses first into the United States and re-crosses into Canada to join the Columbia River on Canadian soil. The American part of the Columbia River System is being developed at a high rate by the United States of America, the biggest dam, Grand Coulee, forming Franklin D. Roosevelt Lake which stretches right up to the Canadian border. Canada has devised a scheme in which 5,000 cusecs of the water of the Kootenay is to be diverted into the Columbia River thus permitting large power developments on the Canadian part of the Columbia River, with very large storage dams to improve the regulation. At the end of this chain of stations it is proposed to divert part of the Columbia River into the Thompson River which flows into the wholly Canadian Fraser River which, in turn, flows into the sea near Vancouver. This diversion would permit very large power developments on the Fraser and Thompson Rivers, measured in thousands of MW, which otherwise would be difficult or impossible of realization because of lack of regulation and very low flow in the winter months which would affect salmon migration. To indemnify the United States for the loss of water in the Kootenay and Columbia Rivers, Canada offers permission to raise the crest of the Grand Coulee Dam by 42 ft., which would cause the reach of the reservoir to extend for many miles into Canadian territory, add 3.3 million acre-feet to its storage capacity and 230 MW to the output of the Grand Coulee Power Station ; they further offer better regulation of the Columbia River and cyclic use of water from one of this high reservoirs during periods of extremely low flow. The legal basis for these negotiations is the Boundary Waters Treaty of 1909 by which the riparian state is vested with exclusive jurisdiction and control over the use and diversion of all waters on its own side of the boundary, subject only, should injury result on the other side, to the same legal remedies as if such injury took place in the country where the diversion or other interference occurs. Obviously, this is not a good basis for optimum international co-operation.

By contrast, a scheme may be described which has been devised with a view to the optimum utilisation of the water resources of an area irrespective of national boundaries, and which safeguards the interests of both countries concerned (Ref. 8). The River Inn has its source in Switzerland in the famous valley of the Engadine which, in its upper part, does not offer suitable sites for storage reservoirs by which the seasonal variability of the flow could be regulated without disturbing the scenic beauty of the valley. A tributary of the Inn, the Speel Greek, has its source over the border on the Italian side and so has the River Adda, which is a wholly Italian river already partially utilised by several power stations. The upper reaches of the Speel and Adda Rivers offer suitable physical features for large reservoirs. In the scheme, which is now under construction, four large reservoirs will be constructed in close proximity, near the saddle dividing the two river basins, two on either side of the border. They will total about 500,000 ac.-ft. and operate in conjunction. The summer water available form the catchment of the Adda River on the Italian side is only sufficient to fill about a third of the volume of the reservoirs. Additional summer water will, therefore, be diverted into the reservoirs from the Speel Creek and Inn River, the latter with the help of pumps, and released during the winter months into both the Inn and the Adda Rivers, thus greatly improving the flow of both rivers and permitting their optimum development. In return for making available her storages for both partners, Italy receives an agreed

quantity of summer water, which is in itself of low value. The pumping of the water during the summer requires 156 million kWh, but the increased winter energy production amounts to more than a thousand million kWh, which have a unit value about four times that of summer energy.

The benefits of the regulation extend to the many power stations, existing and projected, along the whole course of the Inn River which flows through Austria after leaving Swizerland, and then forms part of the boundary between Germany and Austria to its confluence with the Danube. Some of the international stations mentioned before are situated there.

Multiple Purpose Schemes

The generation of electricity is only one of many benefits that can be extracted from the natural cycle of water. Since the Tennessee Valley Authority has set the example, the exclusive use of water for power generation has come to be regarded as wasteful and contrary to the best interests of the nation, if other desirable and realisable purposes can be served as well. In fact, whenever there exists a modern comprehensive plan for the power development of a river system, it is bound to be comprehensive also in the sense that it will provide for a balanced development of various other purposes with the objective of achieving the best overall benefits for the nation. The previously mentioned schemes in India, China, Egypt, etc., are all multiple-purpose schemes.

The Columbia River basin is being developed to provide multiple benefit, including irrigation and flood pervention. Another benefit is slackwater navigation for 320 miles from Bonneville, Oregon, to Lewiston, Idaho, by a series of pools formed by dams. The McNary Dam alone provides a pool extending 61 miles, in addition to premitting the generation of 1,200 MW, and about 5,000 million kWh. Some appprecia-tion of the advantages of combining the various functions in one project is conveyed by the following figures : a dam and lock at McNary to serve navigation only would have cost $142 million ; a dam and power house only would have cost $266 million; the combined development is costing about $121 million less than the sum of the two single purpose projects if these were feasible of realisation as separate projects ; the ratio of benefits to costs is 1.4 to 1 (Ref. 9). In this case, the navigation project was only justified as a part of a double purpose scheme although the power development would have been attractive even as a single purpose scheme. In other cases, power developments may be marginal, and may become profitable or justifiable by combination with, say, irrigation or flood prevention.

In the practice of the United States Corps of Engineers, a multi-purpose project is considered economically justified if the sum of the benefits exceeds the total cost ; furthermore, the benefit for any purpose must exceed the incremental cost for this purpose. The benefits are evaluated as the value of the goods and services produced by the project, for example, the annual net value of agricultural produce due to irrigation, or the damage prevented by flood storage ; but the value of the benefit has a ceiling which is set by the annual cost of the most economical alternative scheme achieving the same purpose.

The equitable allocation of costs for Multiple Purpose Schemes is a matter of intense interest to those who have to pay the bill. It is therefore not surprising that opinions on the best methods to be used differ. The so-called "separable cost—remaining benefits" method will be described briefly as it is claimed by the U.S. Corps of Engineers to be satisfactory under a wide range of conditions. The "separable costs" for each purpose are the costs of those works that can be readily assigned to that purpose, such as a lock to navigation, or a powerhouse to generation. The "joint cost" of the project is the cost left over after deducting all separable costs from the total cost ; the problem is to find a formula for the distribution of these joints cost. To this end the idea of "remaining benefit" is introduced. For each purpose, the project benefit is computed; also the cost of the most economical alternative to achieve a comparable result. The separable cost is deducted from whichever of these two figures is the smaller and we obtain thus the "remaining benefit." The joint cost is then distributed in proportion to the remaining benefits of the various purposes. The share for any purpose plus the separable cost is the total cost for that purpose.

Intergation of Hydro-electric Power into Large Power Systems

The demand for electric power varies continually with time. If a high standard of service is to be maintained, it is necessary that at any instant sufficient power should be generated to meet the instantaneous demand ; the generating capacity in service must provide a margin for unexpected outages of plant and for errors in load forecasting. Some of the installed capacity will at times be idle because there is no market for the energy it is capable of producing.

As soon as there is more than one generating unit on the system to meet the load, the problem of the most economical load sharing arises, with different solutions according to the characteristics of the various units. For reasons already mentioned, the preponderantly thermal system will eventually be the most common, and it is certainly the most interesting one here in Australia at the present time. It shall therefore be singled out for particular attention.

Peak-Hydro Power in a preponderantly Thermal System:

In a purely thermal system, the units with the lowest fuel costs per kWh (usually, but not always, the most modern units) operate on base load ; the higher the fuel cost per kWh of a unit, the smaller will be the capacity factor allocated to it. Due allowance has to be made for transmission losses.

In such a system, storage water power is used to best effect for peak load generation (Refs. 10, 11, 12). This can be shown in a very simplified manner (neglecting some important factors which will be considered later), as follows :

The cost of creating the storage reservoir and collect-

ing the water, i.e., the cost of the dams, racelines, aqueducts, etc., is mainly related to the quantity of water to be collected and stored each year, hence to the amount of energy required to guarantee the rated capacity at the designed capacity factor. The cost of the powerhouse and main plant, penstocks, head and tailraces, transmission, etc., is mainly related to the installed capacity. This incremental demand component of cost per kW is lower than for thermal power stations ; it is therefore economical to meet a high proportion of the system demand by storage stations ; this implies low capacity factor for peak load operation.

Further savings are obtained by the avoidance of banking losses and starting-up and shutting-down losses which would be incurred by low capacity factor operation of plant. It is also profitable to ensure that the high efficiency thermal base load plants operate at steady load near their most economical loading. This is achieved by arranging for the hydro-generators to take the fluctuations of load. A further most important advantage of having a percentage of hydro-generation in a thermal system is the rapidity with which hydro-electric generator sets can be brought into operation in case of emergency and during the morning load rise. To start up and load a hydro-electric set takes about as many minutes as it takes hours for a steam-driven set.

In computing the economy of hydro-electric plant, an adverse factor has to be taken into account (Refs. 13, 14, 39). Because of the steadily increasing efficiency of modern steam generating sets, the overall efficiency of generation of a system tends to increase as new plant is brought into service each year. During the period 1947/8 to 1955/6, the average thermal efficiency of the system of the Central Electricity Authority (Ref. 15) in Great Britain increased from 20.91 per cent to 24.35 per cent, that is, in the average about 2 per cent annum (relative). By developing hydro-electric power rather than adding new thermal power of improved efficiency, this steady improvement in efficiency is interrupted, resulting in a debit against the hydro-electric scheme. However, this adverse effect is only temporary ; it diminishes in subsequent years as the displaced high-efficiency plant would have moved into the region of lower capacity factors (Ref. 16). It is also necessary to add that, in the case of the C.E.A., the average cost of coal increased during the abovementioned period by 51 per cent, an average of 6.4 per cent per annum, considerably outweighing the improvement in efficiency. The increase in generation costs per kilowatt hour averaged 3.2 per cent per annum during that period (Ref. 15).

As an illustration of the practical working of mixed systems, consider Southern Scotland, where one-third of the plant installed is hydro-electric, while two-thirds are thermal. Fig. 1 (from Ref. 17) shows a typical daily load curve. The capacity factors of the hydro peak load stations vary between 10 per cent at Loch Sloy and about 20 per cent in the Galloway and other schemes. As particular advantages of the hydro-electric contribution, are mentioned the high availability and the quick starting of the hydro-plant and the favourable influence of "peak-slicing" on the operation of the steam power stations (Ref.17).

In Germany (Ref. 18), about 80 per cent of the total energy is produced by thermal stations, and about 20 per cent by hydro-electric stations, in roughly equal parts in run-of-river and storage plants. Run-of-river plants in Europe usually have a reduced output during the winter months; this accentuates the need for Winter energy. The storage plants existing in Western Germany at the end of 1954 had an installed capacity of 1,110 megawatts and an average capacity factor of 19 per cent. At that date, further storage plants were projected with an installed capacity of 2,119 megawatts and an average capacity factor of 17.6 per cent. Note the reduction in capcity factor. So anxious is Germany to add to its own inadequate supply of peak-hydro power that large amounts are imported from her southern neighbours, particularly Austria, where many high-head peak power stations have been financed by German capital. For the same reason she has vigorously developed pumped storage to which reference will be made later.

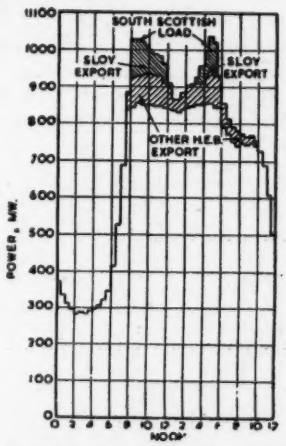


Fig. 1.—Typical Hydro-electric Board Export and South Scottish Load in December 1952.

Source: Haldane and Blackstone, J.I.E.E., 1955, p. 323.

For run-of-river stations the tendency is also to reduce the capacity factor. Existing stations in Germany have an average capacity factor of 64 per cent, whilst those projected will have 59 per cent. The same trend is reported from Sweden (Ref. 19) and other countries.

Peak-Hydro Power in a preponderantly Hydro System

It may be of interest to cast a glance at conditions in Switzerland, which is a preponderantly hydro-electric country as it produces approximately 95 per cent of its energy requirements by water power. As a great portion of its run-of-river, the need for peak energy is accentuated. Similar conditions obtain in Austria. The electricity supply in Switzerland is in the hands of a number of private, semi-private and government undertakings which are closely interconnected and exchange energy on a free market on which the

price is governed by the law of supply and demand. Summer off-peak energy is cheapest, winter peak energy is the dearest, and there is an extra price if winter energy is guaranteed say by being produced from a large storage reservoir The ratio of winter to summer energy price is approximately four to one (Ref. 20).

Because of the great need for winter energy, a large number of storage schemes have been built, or are under construction at an accelerated pace. In 1955, the amount of energy storage available amounted to 15 per cent of the yearly consumption, by 1962 it will be about 23 per cent (Ref. 21)

Table I gives characteristic data of some typical high-head schemes in the European Alps. Two of the most remarkable schemes at present under construction are the Grand Dixence and the Mauvoisin Scheme in the Canton of Valois (Ref. 22), which when completed will produce over 1,000 megawatts at an average capacity factor of 26 per cent about 85 per cent of the energy being produced in winter. The extent of the civil works, as indicated in Table I by the concrete volumes in the dams, and the lengths of collecting aqueducts, is an indication of the high cost of this power. Of interest is the independent development of these two schemes in close proximity by two different organisations.

Pumped Storage Schemes:

The principle of storing water for ready conversion into electrical peak energy when needed can be extended by filling the reservoir by pumping water from a lower level (Refs. 23, 14). The pumping is done during off-peak periods when surplus energy is available, either from run-of-river hydro-electric stations or from thermal stations with a low fuel cost per kWh. The main advantages over ordinary hydro-electric storage stations are that peak power is assured independently of natural inflow into the storage basin, and that pumping can be used to increase the capacity factor of thermal plant of intermediate loading with a corresponding fuel saving and reduction of wear and tear. Pumped storage can be considered as a conversion of base load or surplus energy into peak load energy, the overall efficiency being of the order of 60 to 67 per cent.

TABLE I

EXAMPLES OF MODERN HIGH-HEAD STORAGE DEVELOPMENTS

Name	*Gross head (ft.)*	*Power developed (MW*	*Total Energy per annum (kWh 10^6 Winter)*	*Capacity factor (%)*	*Principal dam*		*Volume of dam (10^6 cu. yd)*	*Storage (ac. ft.)*	*Main tunnels*		*Aqueduct and subsidiary tunnels miles*
					Type	*Height (ft.)*			*miles*	*diam. ft.*	
1. *Grande Dixence*											
P.S. Fionnay	2530	320	1650	27.3	Concrete Gravity	930	7.7	284×10^3	16.6	9.8—13.4	65
P.S. Nendaz	3220	366									
Total	5750	686	(1450)								
2. *Mauvoisin*											
P.S. Fionnay	1550	127.5	761	24.7	Concrete Arch	775	2.75	146×10^3	12.8	9.7—10.6	8.5
P.S. Riddes	3330	225.0	(604)								
Total	4880	352.5									
3. *Glockner-Kaprun*											
Upper P.S.	1190	112	615	21.2	Concrete Arch	365	0.31	69.5×10^3	7.18	8.8—11.8	12.5
Lower P.S.	2920	220	(469)			394	0.59	68.5×10^3			
Total	4110	332									
4. *La Lienne*											
P.S. De Croix	2810	54.2	184		Concrete Arch	425	0.43	40.5×10^3	6.5	5.3—7.2	3
P.S. St. Leonard	1360	28.6	(153)	25.2							
Total	4170	82.8									
5. *Zervreila*											
Seekraftwerk	417	20	533	26.4	Arched Gravity	495	0.89	81×10^3	21.3	6.9—11.8	
Safien Platz	1395	75	(326)								
Rothenbrunnen	2210	110									
Total	4022	205									
6. *Gougra*											
P.S. Motec	2240	69	317	22.0	Concrete Arch	480	1.05	60.5×10^3	11.6	3.62—7.9	5.6
P.S. Vissoie.	1440	45	(207)								
P.S. Chippis	1940	50									
Total	5620	164									

Pumped storage plants can be located in convenient proximity to large centres of generation and consumption, provided there is a possibility of creating two reservoirs with a suitable difference in level. The upper reservoir is sometimes constructed entirely artificially by means of dykes on hill tops. For a daily cycle, i. e., pumping at night and generation during daytime, only small reservoirs are required.

Pumped storage plants can also be located in the high mountains; in this case they are often conceived as an extension to a conventional high-head storage development. Their incremental cost is then particularly low as the reservoirs are already provided. Such schemes have been proved economical even though the cost of the peak energy is loaded by the additional cost of transmission due to remoteness from the centres of generation and consumption.

The technique of pumped storage is already 70 to 80 years old (Ref. 24) but the first large stations were constructed in the 1920's and 1930's in Germany and Switzerland. There are about one million h. p. in service on the Continent. Recently, the idea has spread to Great Britain, the U. S. A. and other countries. Table II indicates the main characteristics of a selection typical schemes.

same mode of operation is invaluable in assisting the frequency regulation of large networks.

Some recent schemes are described hereunder :

Ffestiniog Scheme (Ref. 14). In the United Kingdom, the problem of meeting peak demands is becoming acute through the introduction of very large thermal generating units (200 megawatts) which take a long time to start and shut down, and also through the advent of nuclear power. As storage hydro-power is limited, the C.F.A. are taking an active interest in pumped storage schemes. Construction has begun on a scheme at Ffestiniog, in Wales, the principal features of which are.—

Installed capcity	300 megawatts in four 75-MW sets.
Generated energy	300 million kilowatt-hours p.a.
Normal pumping period	7 hours per day.
Normal generating period	4 hours per day.
Range of gross head	981 to 1059 ft.
Daily capacity factor	16.7 per cent.
Annual capacity factor	11.4 per cent.

TABLE II

EXAMPLES OF PUMPED STORAGE SCHEMES

Station	*Country*	*Generating Capacity* (*MW*)	*Pumping Capacity* (*MW*)	*Energy* (10^6 *kW-hours p.a*) *From Pumping*	*From Natural Inflow*	*Capacity Factor* (%) *For Total Energy*	*For Pumping Energy*	*Approx Gross Head* (*ft.*)	*Completion*	*Remarks*
Hausern	Germany	4×32	4×20	263	487	19.4	6.8	680	1931	Seasonal peak
Witznau	,,	4×44	4×32					765	1943	
Waldshut	,,	4×35.2	4×18					535	1951	
Etzel	Switzerland	2×14.7	2×16	30	122	19.7	3.9	1568	1946	Daily and weekly peak.
Graimsel-Oberaar	,,	1×31	1×19.5	69	—	—	25.4	1312	1954	Seasonal peak.
Our-Vianden Stage I	Luxembourg	4×80	4×53.7	435	—	—	15.5	920	Under const.	Daily peak.
Ill-Rodund	Austria	4×42.5	4×40	359	972	39.3	10.6	1125	1952	Daily peak.
Ill-Lunersee	,,	5×37.2	5×42.5							
		1×31	1×41					3220	Partly Completed	Daily and seasonal peak.
Flatiron	U. S. A.	1×8.9	1×8.9					290	1954	Daily peak.
Hiwassee	,,	1×63	1×76			25.1		290	1955	Daily peak
Sir Adam Beck II	Canada	6×34.2	6×34.2					85	1957	Daily peak.
Ffestiniog	Britain	4×75	4×62.5	300	—		11.4	1021	Under const.	Daily peak.

An interesting development of pumped storage consists in using the pumps as an indirect spinning reserve, i.e., by pumping during normal full-load operation thus loading steam plant which otherwise would only be partially loaded to provide a spinning reserve. In case of loss of generation, pumping is at once discontinued, thus freeing an equivalent amount of power. By subsequently changing over to turbine operation, the sum of turbine and pump capacities becomes effective as system reserve. In addition, the loss of fuel economy often caused by the provision of spinning reserve is circumvented. The

The cost of the scheme is estimated at £ stg40 per kilowatt excluding transmission which will cost a further £ stg7.5 per kilowatt.

Economic assessment of the scheme has shown that substantial financial advantages will be dervied both from its normal operation as peak load plant, in which its low capital charges are the important factor, and from its use at other times as immediately available standby capacity with resulting savings in banking losses in the thermal plant which must otherwise perform this duty. Other schemes are under considera-

tion, some of which are even cheaper. In general, the capital cost per kW of pumped storage stations in Great Britain is about half the cost of modern coal-fired stations.

Development on the River Our, Luxembourg (Ref. 25). This scheme is based on the availability of low cost thermal "offpeak" power in the nearby industrial regions of the Ruhr, the Saar and the Lorraine, and also of surplus water power from the run-of-river stations on the Rhine. The Societe Electrique de l'Our (SEO) was formed in 1951 and consists of representatives of various French, Belgian, German, Dutch, Swiss and Luxembourg supply undertakings and the Luxembourg Government. Station capacity in the first stage will be 320 MW in four sets, each set consisting of an 80-MW turbine, a 100-MVA generator-motor and a 53.75-MW pump. The station will be underground. The lower basin will be formed by an 82-ft. high dam on the River Our with a useful storage capacity of 1,850 ac.-ft. in the first stage and twice that figure in the second stage. The upper storage of equal volume will be artificially created by means of an earth dyke at a head of 930 ft. The cost is estimated at 4,700 Fr. Lux. (£A42) per kilowatt.

Various methods of operation are envisaged.—

(i) The Company purchase for pumping cheap energy, available in neighbouring systems, convert it into peak energy and sell this peak energy.

(ii) Alternatively, one or several sets may be put at the disposal of a supply system for an annual lump sum. The system can then use these sets according to its requirements.

(iii) As a further alternative, the pumping energy is made available to the Company free of charge and in return the Company restores a certain percentage of it as peak energy, the balance being retained for sale elsewhere.

It is thought that these various methods of operation may ultimately be combined, the choice depending on the operating conditions in the neighbouring networks. There are indications that the second stage of the scheme will not be long delayed. The development of nuclear power stations is expected to accelerate the need for the second stage, which will bring the capacity to 640-MW.

Pumped Storage in Western Austria : It has already been mentioned that Germany imports a great deal of peak power from Austria. The Vorarlberger Illwerke operate a number of high-head storage power stations, a pump storage station at Rodund, and are now building one at Lunersee. These stations are linked hydraulically and operate in conjunction (Ref. 26). The Lunersee Reservoir is intended for seasonal and daily storage and requires pumping for complete filling. The Rodund station operates on a daily cycle only. In conjunction with two existing high-head developments, this group of stations will provide the largest block of peak power in Europe, i.e. 570 MW of generation using 330 MW of pumping power. This represents a total "regulating range" of 900 megawatts which can be used for frequency regulation or quickly available reserve. Pumping energy is drawn from the German brown coal-fired power stations over distances of the order of 1,000 km. Pumping is used to even out temporary drops in load in the interconnected system such as during the mid-day break.

Nuclear Energy and Hydro-electric Power

Nuclear power stations will have higher capital cost and lower running cost than other thermal power stations; they will therefore be run as base load stations at the highest possible load factor (Ref. 27.) It follows that they will displace coal-fired steam power stations, including the most modern ones of very high efficiency, into a region of lower capacity factors, probably of two-shift operation which will increase their fuel rate; it also follows that the peak loads will have to be provided by non-nuclear types of power stations, more suitable both technically and economically for this purpose. The programme for nuclear power stations in the U. K. provides for 5,000 to 6,000 megawatts by 1965 (Ref. 28); to supplement this huge base load capacity, large amounts of peak load plant will be required. Because of the limited resources of hydro-electric storage potential in England and Wales, a number of schemes for pumped storage operation are being envisaged, as already mentioned. The advent of nuclear power greatly strengthens the case for peak load hydro-power and pumped storage schemes.

Integration of Power Systems across National Boundaries

As different countries are differently endowed with primary energy resources, some having ample coal reserves and little water power, others ample water power and no coal, there is a strong economic incentive for integrating the operation of their power systems. This trend is particularly noticeable in Europe because of the samaller size of nationally sovereign areas which are, therefore, less likely to combine complementary power resources within their boundaries. As a consequence, the international interchange of energy had already been developed after the First World War in particular locations. Since the Second World War, this movement has been greatly stimulated by the Organisation for European Economic Co-operation and other international agencies which aim at a general integration of the economies of European countries (Ref.29). There exist specialised committees and study associations to bring about the development of large amounts of water power in Yugoslavia and Austria, countries that are still rich in water power but poor finance, for export to France, Italy and Germany. The important implication here is that the receiving countries will be dependent to a substantial degree on energy resources outside their control.

An organisation entitled "Union for the Co-ordination of the Production and Transmission of Electricity (U.C.P.T. E.) (Ref. 30) was founded in 1951 and comprises 33 supply undertakings belonging to 8 different European countries, viz. Austria, Belgium,

France, Italy, Luxembourg, Netherlands West Germany and Switzerland. It is concerned with the intensification of the interchange of electrical energy across the borders of the member states for the purposes of increased efficiency, improved service, mutual assistance in cases of emergencies and co-ordnation of maintenance programmes in thermal power stations. A saving in capital should result from this co-operation.

During summers of exceptionally low river flows, the members of the U.C.P.T. E. were able to assist Switzerland with considerable amounts of thermal power, on one occasion up to 25 per cent of its daily production; other countries have benefited similarly. One aspect repeatedly emphasized by writers on the subject is the mutual understanding for each other's problems, engendered by international co-operation in the energy field, which it is hoped will be of lasting benefit in other directions, economic and political.

The proposed interconnection between the systems of Britain and France (Ref. 31) through a submarine cable across the Channel, is well-known; the capital cost of the project is expected to be saved by the reduction in generating plant alone, made possible by the diversity of peak demands between the two countries.

The international interchange of power requires, and is assisted by, the establishment of a power transmission system. A number of European countries are building, or are planning to build, 380-kV transmission systems which ultimately will form a grid covering the whole Continent. An interesting aspect of the international exchange of energy is that quite often one country acts as the transmitter of energy between two of its neighbours; in actual fact, the energy transfer usually occurs by displacement, not physically.

Development in Design

The trend to underground construction of power stations originated in Scandinavia (Ref. 32) and has been spreading to other countries. The main advantages are: greater flexibility in the choice of sites and better utilisation of heads; shorter penstocks (which is important for high heads and large diameters); the possibility of using pressure shafts in rock with a saving in steel by allowing the rock to take some of the load; protection against avalanches, rock falls and bush fires; improved continuity of construction independent of weather and greater ease of maintenance and reduced repair costs in unfavourable climates. A further aspect, which is not often claimed to be decisive, is that of defence. It is only fair to admit that power stations are sometimes put underground because there is nowhere else to put them.

At the other end of the scale we find that semi-outdoor power stations are becoming more popular because of the savings in costs of power house super-structure. The generators are protected by hatch covers, and a large gantry crane is provided for erection and maintenance. The St. Lawrence project will have semi-outdoor generators, in spite of rigorous climate.

In striving for greater economy and efficiency there is a tendency to use Kaplan turbines for higher heads than have been customary not long ago, thus encroaching on a range of heads which used to be the preserve of Francis tutbines (Refs. 33, 40). Similary, are encroaching on the province of Pelton wheels for ever-increasing heads in an endeavour to achieve better efficiency, higher speed, reduction in first cost and avoidance of lost head. Fig 2 shows typical limit

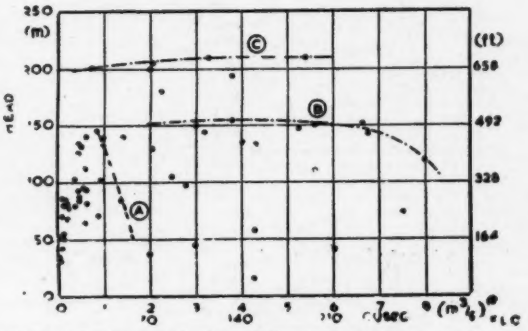


Fig. 2.—Development in the Building of Storage Pumps in Switzerland.

(*A*) Limit curve for the designs up to the First World War.
(*B*) Limit curve for the designs up to the Second World War.
(*C*) Limit curve for the designs up to 1955.
Source: *World Power Conference* 1956. *Report* 235*H*/42.

An improvement is achived by a two-speed generator which can be operated at a higher synchronous speed curves illustrating this tendency. Maximum head of installed Kaplan turbines is 200 ft. (Bort la Rue). Maximum heads for large Francis turbines are about 1,500 ft. at present (Fionnay), but even higher heads are under consideration. Finally, Pelton turbines also are being built for higher heads than before, mainly thanks to improvements in penstock design. The highest head at present used is 5,800 ft. at Reisseck in Austria.

The growing need for pump storage scheme has led to the construction of very large pumps for increasing head per stage; (Ref. 33), Fig. 3 illustrates this. In most cases, a claw coupling will be adequate. If the pump is to be connected or disconnected from the rotating system whilst it is in operation, the pump runner has to be brought up to synchronous speed by by a small starting turbine, the drainage of the pump during starting being achieved by means of compressed air. For multi-stage pumps, the blowing out and refilling of the pump casing presents difficulties. In such cases, a hydraulic torque converter can be used, (e. g. Luncersee Pump Turbine Set), the pump casing remaining filled with water during starting. Sometimes special booster pumps are provided on the suction side which permit a higher setting of the pump and hence savings in excavation cost.

Because of the complication of pump-turbine sets and the additional excavation, in the case of vertical-shaft set , the problem of designing a combined pump-turbine has exercised many minds. One solution is to reverse the sense of rotation for pumping, but in order to obtain reasonable efficiencies for both turbine and pump operation, a compromise runner has to be designed which is not entirely satisfactory for either.

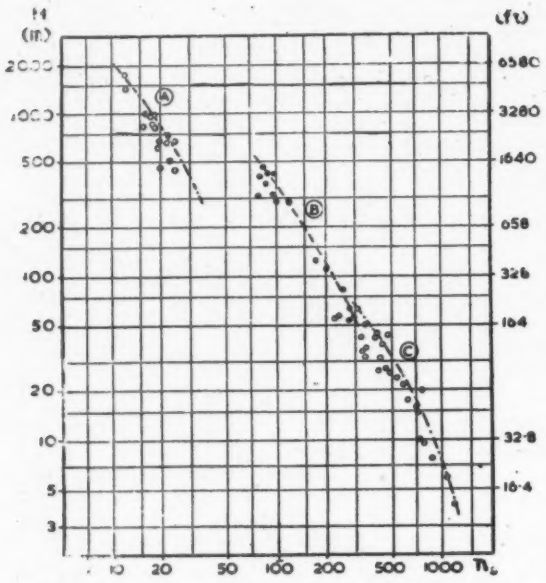


Fig. 3.—Limit Figures for the Maximum Head H as Function of Specific Speed n_s

$$n_s = \frac{n\sqrt{P}}{H^4\sqrt{H}}$$

(*A*) Impulse turbines n_s per nozzle for H_{max}.
(*B*) Francis turbines n_s per runner for H_{max}.
(*C*) Kaplan turbines n_s for H_{max} and H_{min} of the plant.
Source : *World Power Conference* 1956. *Report* 235*H*/42.

as a pump motor resulting in a substantial improvement in efficiencies (Ref. 34).

For low and medium heads, a new type of combined pumpturbine has been designed by Deriaz, which has been installed for the first time at the Sir Adam Beck pumping station (Ref. 35) for a speed of 92.3 r.p.m., a turbine output of 45,000 h.p. at 83-ft. net head and a pump discharge of 4,050 cusecs at 90-ft net head.

In order to obtain the maximum advantage for pump storage stations, as a momentary reserve in an emergency or for quick changing over to pumping during brief reductions in load, it is necessary to make the starting and topping automatic. Typical starting and stopping diagrams for pumped storage sets indicate that turbine operation at full load can be achieved in as short a time as 90 seconds from rest; transition from full turbine to full pumping operationwith in 60 seconds, and the reverse transition in 45 seconds. The station are often under remote control from a central point. For example, the German Schluchseewerk controls power stations for a total rating of 524 MVA and with units up to 60 megawatts, from a single control centre located at a distance of up to 400 mlies (Ref. 18).

Tidal Power Stations

Great progress has been made in this field since the amous Severn project (Ref. 36) has been investigated. The difficulty with earlier projects was, of course, that as the power output follows a cycle which has no relationship to the demand cycle, no demand value could be ascribed to these schemes. Nevertheless the energy could be usefully absorbed in a sufficiently large system like the British system, with a consequent saving in coal, but high cost of the civil works did not make these earlier projects particularly attractive. In the French project, which is at present being constructed on the Rance estuary (Refs. 37,38) the cost has been reduced by a design of a combined turbine generator suitable for mass production and requiring less expensive civil works. The generator is contained in a bulb which is completely immersed in the water; the whole unit can be lifted out for maintenance. At the Rance Power Station, 38 units of 9-MW each will be installed. The water wheel is of the Kaplan type and can operate as a turbine or a pump in two directions of flow, or act as an open gate. The flexibility thus achieved permits a very large number of different working cycles which can be adapted to the requirements of the power system; as a result, the station acquires a firm demand value. This development is also of interest in respect to inland rivers as it may open the way to the utilisation of low heads which could not otherwise be economically developed.

Conclusions

From this rapid survey the following broad conclusions can be drawn :

There are still tremendous potentialities for hydro-electric power inlunder-developed countries. Industrially advanced countries, on the other hand, can already foresee the time when their water power will be fully utilised. Hydro-electric energy will meet a diminishing percentage of the insatiable energy needs of mankind. Nevertheless, it has a vital role to play. In a preponderantly thermal system—and most systems will sooner or later be preponderantly thermal—hydro-electric power is particularly well suited, techincially and economically, to supply the peak loads.

With coal and oil becoming more scarce and expensive, the world is turning to nuclear energy. Its characteristics of high capital and low running costs further enhance the attraction of peak hydro-power, and when the natural water cycle is fully exploited, an artifical cycle can be readily created by employing pumped storage. One can therefore conclude on the reassuring note that hydro-electric engineers should never be out of work.

Acknowledgment

The permission of the Commissioner of the Snowy Mountains Hydro-Electric Authority, Sir William Hudson, to publish this paper is gratefully acknowledged. Thanks are also due to several of the author's colleagues for helpful criticism and comments.

Any views expressed are the author's and do not necessarily represent those of the Snowy Mountains Authority.

[*Continued on page* 26

Durgapur Thermal Power Station and the Coke-Oven Gas Grid

By A. K. BHAUMIK

The State of West Bengal can prosper only through industrial expansion after its loss of agricultural wealth due to partition. The selection of industry should be such that (i) its raw materials are amply available within the State, (ii) it can absorb a good number of middle class educated persons and solve to some extent the unemployment problem and (iii) the products have a ready market to make the scheme a commerical venture.

"Coal" is the only material which can fulfil the above three objectives and as such the new industrial Bengal must be based on coal and its derivatives. In this respect, the position of Bengal is in many ways similar to the economy of England, Germany and Holland where coal is the principal material in industrial development. West Bengal must, therefore, endeavour to derive the maximum benefit from the utilisation of this valuable raw material. With this background, the Durgapur Project, which has immense industrial possibility, has been conceived. It may be stated that Durgapur Project is not a plan with an immediate or restricted objectbut is a nucleus of the basic chemical industry with a definite objective for each phase of development. The phases are also so planned that each phase may be taken as a self-contained, viable economic unit. The general scope of the Durgapur Project (divided into major phases and sub-phases) is shown in diagrammatic sketch (figure 1). The sketch also emphasises the integrated nature of the Project as the economic success of the same largely depends on such integration.

The State Government, before taking a definite decision in this regard, appointed some time back Dr. C. Octo and Company, reputed Consulting Engineers of Germany, to study the proposal in detail and to recommend the first phase of the project for immediate implementation. The Consulting Engineers accordingly prepared a Project Report and recommended erection of by-product Coke-Oven Plant, Gas Grid and Thermal Power Station. Besides laying the foundation for coal chemistry in India, its aim is to meet increasing demand of coke in West Bengal, profitable utilisation of by-product coal gas for domestic and industrial purposes in Durgapur and Calcutta area and other towns en route. The Consuting Engineers suggested installation of a Thermal Power Station as an adjunct to the Coke-*cum*-Gas Plant and strongly advocated torun the whole system as a compound and integrated unit for the following economic reasons:

(a) During the initial stage, demand for coal gas may not be sufficient to consume all the gas generated and the surplus by-product gas may very conveniently be utilised in Thermal Power Station for steam rasing purpose. The surplus gas would otherwise have been a complete waste.

(b) Utilisation of high ash content coal in Ranigunj area for local power generation.

The State Government noted with interest the heavy demand of power on the DVC system of such magnitude that the entire output of the Corporation's generating stations are practically booked even from early construction stage. Figure 2 shows the load development and power position in DVC system as recently surveyed and estimated by the Central Water and Power Commission. It was, therefore, thought proper that the State Government must have a thermal power station of its own for supply of adequate cheap electricity to Coke-Oven and Gas Grid Plant of Durgapur Project as well as to important industries at Durgapur and adjoining areas than to bank on the uncertain position of DVC's supply at higher cost detrimental to the very object of the above schemes. Further, integration of Coke-Oven Plant with the Thermal Power Station would undoubtedly help each other to achieve most economical operation of the individual plant and result in earlier financial success by minimising waste, the most noteworthy feature of the entire project. Utilisation of surplus gas and operational cycle of boiler steam and condensate feed water in compound operation of power station with coking plant are shown in figures 3 and 4.

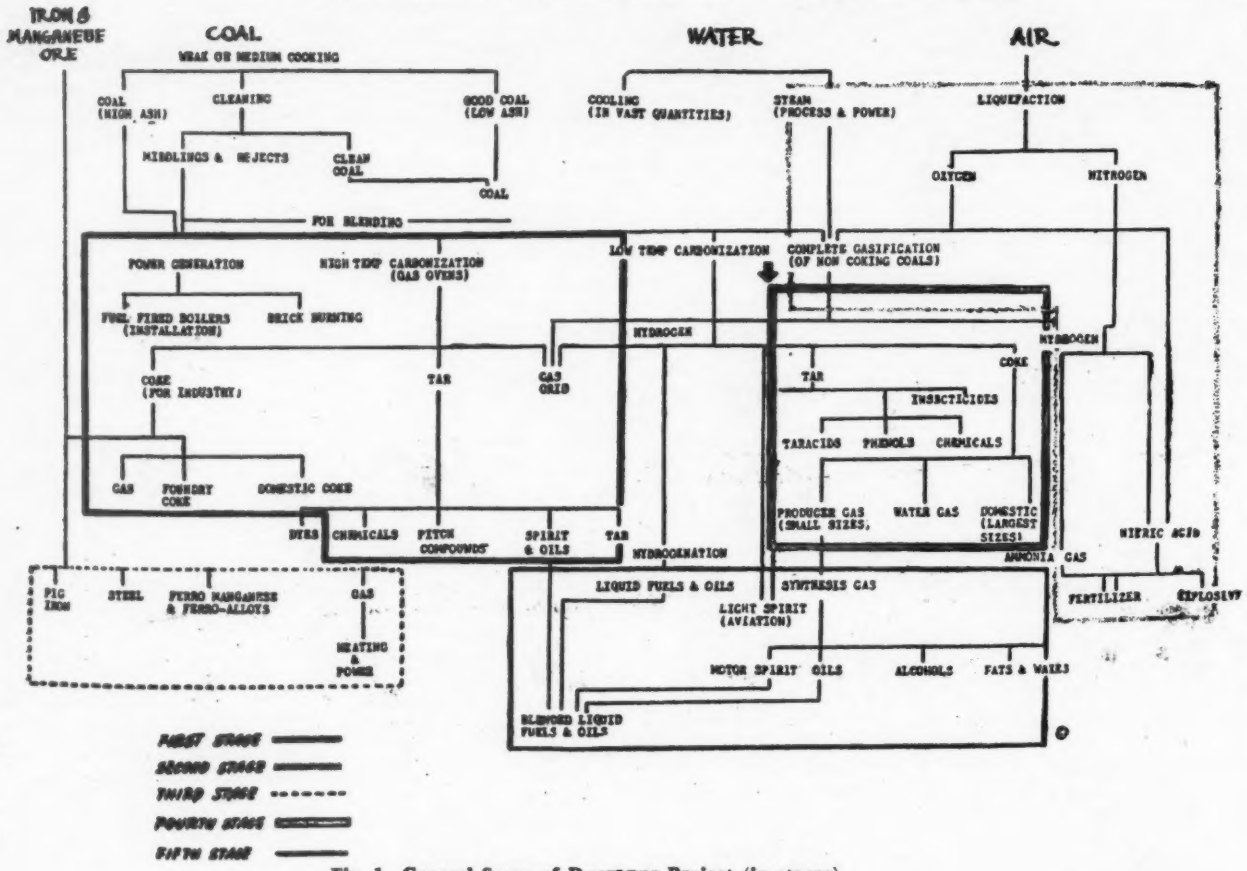


Fig. 1. General Scope of Durgapur Project (in stages)

The first phase of the project has therefore, been to be the following for immediate implementation during the Second Five-Year Plan :

(*i*) One 1,300 ton per day capacity Coke-Oven Plant with a Tar Distillation Plant and other ancillaries for treatment of by-products.

(*ii*) A Statewide 15 million cubic feet gas distribution system consisting of a trunk pipe line between Durgapur and Calcutta on the one hand and Durgapur and Chittaranjan on the other.

(*iii*) One 60,000 kW. capacity Thermal Power Station, which will utilise pulverised low grade coal and/or coke-oven gas as the case may be and with arrangement for production of process steam required for the Coke-Oven and Chemical Plant.

Durgapur as Site

While preparing the Project Report, the German Consulting Engineers commented that in selecting the site at Durgapur for the Coking Plant, etc., the Government of West Bengal made a very favourable choice, taking into account all conditions required for the industrial development. The climate of Durgapur area is congenial and the land is suitable for building industrial units. The transport facilities are excellent as there will soon be an electrified 4-track railway, major highway and a canal linking this area to the consumption centre and the port. Raw materials for industrial development, e.g., coal, refractories, gas, power and water will be available in plenty in the immediate neighbourhood. From all aspects, therefore, the site of major growing industrial area at Durgapur is ideal and in fact the only area in Bengal where industries can be quickly developed in the immediate future.

From Thermal Power Station point of view also, the town of Durgapur offers the following advantages :

(*a*) Proximity of abundant coalfields to the Power Station.

(*b*) Availability of abundant water from the barrage of the DVC across the Damodar river.

(*c*) Its central position as to the load of the Power Station.

Power Demand and Capacity of Generating Station

For economic, technical and other reasons, the Consulting Engineers suggested that the capacity of

the power station should be of 60 mw. at the first instance with adequate provision for future extension. Due to tremendous industrial possibility in the near future, it was also decided that the Power Station would be so designed as to achieve augmentation with minimum cost and time. Within a short time and long before the State Government's Power Station is put to commission, the picture of load growth and supply position in the Durgapur area has completely changed. The growth of load is so meteoric that the Damodar Valley Corporation, in spite of their second thermal station of 2×75 mW. at Oriya, finds it difficult to meet its commitments to various industrial consumers in the Valley area. To promote industrial development for earlier success of the project the State Government has also commited to supply power to numerous industries cropping up at Durgapur in addition to rural electrification and Coke Oven and Gas Plant. As the aggregated demand of such industries outweighed the firm output of the station, there is hardly any possibility of relief to the Corporation from the State Government's power station at Durgapur.

Leading of the station to the full extent from the very start would result in the earlier final success of the project.

Brief Description of the Power Portion of the Project

Present project envisages the generation of electricity at Durgapur with two 30,000 kW. thermal turbo-alternator sets with provision for future extension. Generation would be done at 6 kV. and then it would be stepped up to 132 kV. at the adjoining main sub-station for inter-connection with DVC grid running to Burdwan and then to Calcutta. Arrangements would also be made to supply power direct from the Generating Station to the adjoining coke and gas plants, new industries and local town electrification schemes.

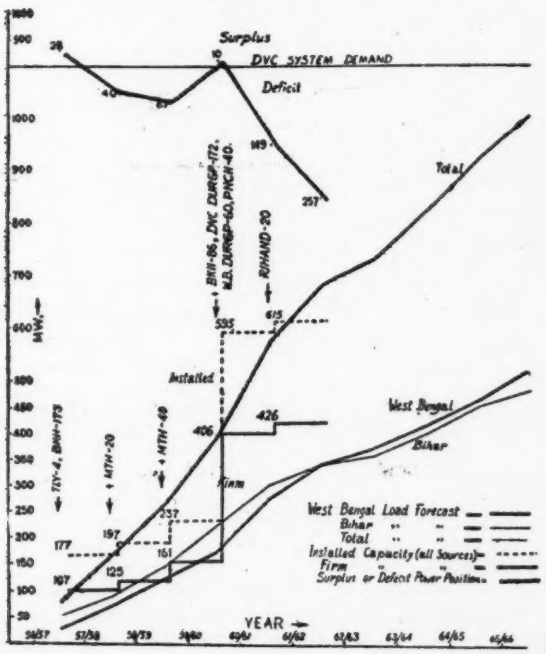


Fig. 2. Load development and power position in DVC system as assessed by C. W. & P. C.

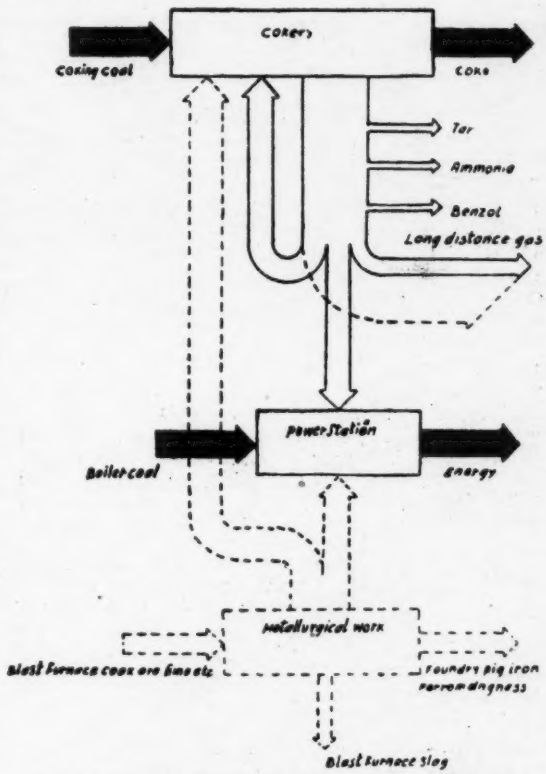


Fig. 3. Compound operation of Power Station with Coking Plant—Utilisation of surplus Gas

Capital expenditure of the project is estimated to be about Rs.6 crore and the scheme is expected to be self-supporting from the very beginning, due to the loading of the station to the full extent practically from the time of its commission.

Advantage of Compound Operation

It has already been mentioned that mainly inferior fuel, with high ash content shall be used in the power station. During the initial years of operation, considerable quantities of surplus gas will be available from the Coking Plant for firing the boilers.

The steam turbines of the sets are designed for bleeder steam, which would be branched off for use in Coke-Oven and Gas Plant. In the former, to avoid contamination, this steam would in turn generate steam required for Coking Plant by means of special process steam generators. In the latter, the used steam, after purification from oil, would be condensed. The condensate steam in both the cases would then be returned to the boilers as feed water without any

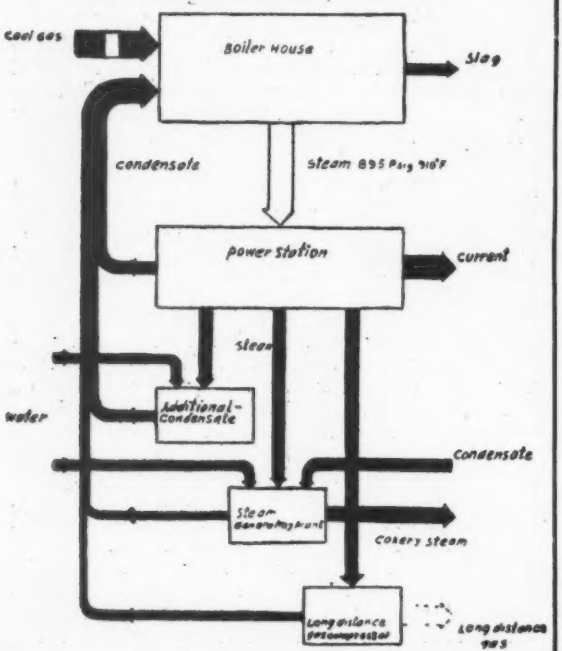
oss. This compound operation would enable the gas compressors as well as the Coking Plant to be supplied with 15 tons/hour of steam each without any loss of condensate for feed water.

Financial Aspects

In accordance with the agreement entered into with various suppliers, the power portion of the Durgapur Project would cost about Rs.6 crore. Fixed and operational expenditure of maintaining such thermal station would be about Rs. 50 lakh excluding the cost of fuel. Although during initial years, the thermal station would be run mostly on surplus gas of Coke-Over Plant, yet to make the power portion of the entire project a self-supporting and complete unit, usual cost of coal as required for an independent power station is assumed. Overall thermal efficiency of 28 per cent. is expected to be achieved in economic loading and running of the sets. The calorific value of grade II coal in Ranigunj area varies from 10,400 to 10,800 B.Th.U. per pound and the average value of 10,600 B.Th.U per pound is taken for estimate. Coal base has been assumed to be Rs.15.25 per ton inclusive of transport, siding and cess charges.

Loading of the power station to the full extent practically from the beginning of operation would ensure financial self-sufficiency of power portion of the project practically from its commencement. During the initial years, considerable fuel would be saved due to utilisation of surplus gas and the same in turn would improve the overall financial picture of the entire project.

Fig. 4. Compound operation of Power Station with Coking Plant —Operational cycle of Boiler Steam and condensate feed water



The Coke-Oven and By-Product Plant

The total estimated cost of the Durgapur Coke-Oven Plant is Rs. 14,10,81,000 which includes Rs. 7,26,00,000 for the Coke-Oven and By-product Plant, Rs. 6,55,00,000 for the Power Plant and the expenditure on Development of Subsidiary Industries.

The Planning Commission's Programmes of Industrial Development, 1956-61, give the following details of this major State undertaking under the Second Plan :

Carbonisation capacity	1,300 tons of throughput of coal and coke-breeze per day.
Production capacity for coke	930 tons of coke per day or 325,000 tons of coke per annum.
Capacity for sized coke plus I	292,950 tons per annum.
Ammonia	1,500 ,,
Sulphuric Acid	3,300 ,,
Motor benzol available for sale	552,000 gallons per annum
Benzene, toluene, solvent naphtha and xylene for sale	792,000 ,,
Still bottom oil	100,000 ,,
Road tar	9,286 tons per annum.
Naphthalene	682 ,,
Wash oil	1,900 ,,
Other tar-distillation products	3,743 ,,
Coke-oven gas (surplus for sale 460 BTU per cubic feet)	2,863 million cubic feet per annum.

The coke-oven gas is expected to be utilised, in the first stage, as a fuel in the 60,000 kW. power station, which it is proposed to establish in conjunction with the Coke-Oven Plant. The West Bengal Government have also under consideration a plan for piping the gas to Chittaranjan and Calcutta for sale as industrial and domestic fuel; a final assessment of this proposition will be made in the light of the situation obtaining in 1958. The manufacturing conditions and technique adopted by this Coke-Oven Plant will be based on the results of pilot plant experiments of various coal blends carried out on a half-ton oven by the Fuel Research Institute. The efficiencies and yields claimed in this plant are expected in most cases to be substantially higher than those achieved so far in any of the coke-ovens or coal-tar distilleries operating in the country.

From the sale of the entire ouput of different products obtained from the operations of the plant, a gross return of Rs.1.93 lakh per annum is expected as against manufacturing charges, provision for depreciation and interest on working capital amounting to Rs.1.58 lakh.

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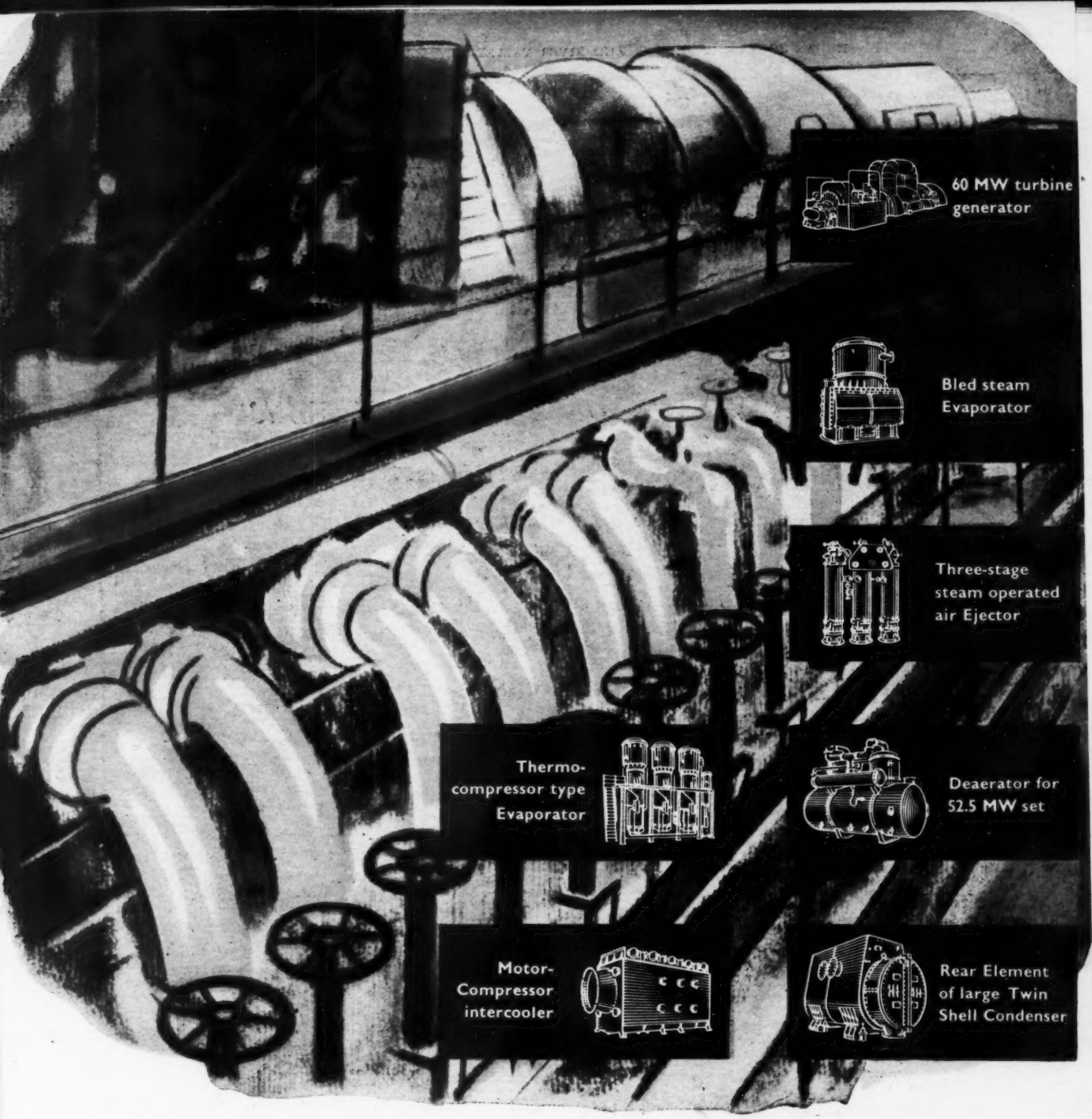
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Mining Scheme

The Government of India sanctioned the mining part of the scheme at a cost of Rs. 16.90 crores. Special care was taken in the layout of, and the arrangements in the field machinery station and the repair shop; the construction and equipment of these were completed in May, 1957 with the exception of one or two minor jobs. The staff needed for the initial stages of the mining scheme was recruited in time and trained at site.

Messrs Powell Duffryn Technical Services were appointed as Consulting Engineers for the mining scheme for a period of 3½ years from 10th May, 1957. Earth-moving operations were inaugurated by the Prime Minister on 20-5-1957. The work involves the removal of overburden amounting to 27,000,000 cubic yards before lignite will be exposed, by the middle of 1960. The earth-moving machinery was intended to be worked in two shifts, giving a total output of ten hours per day. On this basis, the target for the removal of overburden for the year 1957-58 was fixed at 4,000,000 cubic yards. As most of the operators for the machinery, who had been selected from other Projects nearing completion, could not join in time, and as foreign exchange releases for the import of electrical materials such as tubular poles essentially needed for the extension of electric supply to the initial mine cut area also presented some difficulty, the second shift could be started regularly only from the middle of September, 1957. In addition, there was delay in the working of the two electric shovels on account of heavy monsoons and a large number of working days was lost. The target had, therefore, to be reduced to 3 million cubic yards, against which a total of 2.655 million cubic yards of overburden had been removed by the end of February, 1958. In regard to specialised mining machinery, the suppliers reported a possible delay in the delivery of the equipment on account of strikes in their factories for a period of four months. A few parts of the belt conveyers and the rubber belting have been received at site, which will be commissioned as soon as the specialist erectors arrive there from Germany. A target for the removal of 5 million cubic yards of overburden has been set for the year 1958-59. Pumping experiments with wells, drilled in circular pattern and located 100 ft. apart, near the mine cut, for determining the best method of drilling and the right type of well-screen to be used in the tube-wells to be sunk for depressing the artesian water pressure below the lignite base are also in progress. The services of two German Drilling Experts have been obtained through the good offices of the West German Government, free of charge to the Corporation, for a period of three months to train the Project staff in the latest methods of drilling. These two Drilling Experts arrived at Neyveli in the last week of December, 1957 and have commenced their work.

Scheme for the Generation of Power

The Planning Cell of the Central Water and Power Commission who were engaged on the designing of the Thermal Power Plant had prepared all drawings and calculations essential for the Power Station and the plants. A Project report with detailed specifications for the power plants had also been prepared. In the meantime, it was decided that the Thermal Power Station scheme would be financed from out of the credit of 500 million roubles offered by the Government of the U.S.S.R., under a Indo-Soviet Agreement concluded on 9-11-1957. A subsidiary contract was signed by the Lignite Corporation with Messrs Technoexport, Moscow, on the 14th December, 1957. In accordance with its terms and conditions, the Russian specialists visited Neyveli in December, 1957, to gather site and other initial data, besides other particulars for the construction of the Thermal Plant. The detailed specifications already prepared by the C.W. & P.C. will be utilised by the Soviet specialists to

prepare, in consultation with our own experts and in accordance with the standards, characteristics of equipment and technical conditions for designing existing in the U.S.S.R. and also taking into account the local conditions and regulations in India, a detailed project report which would facilitate the placing of orders for the supply of equipment. This report is to be submitted by the Soviet authorities by September, 1958.

Scheme for the production of Fertilizer

It has been decided that the entire quantity of nitrogenous fertilizers to be produced at Neyveli should be in the shape of Urea only. A detailed project report for the fertilizer plant for the manufacture of 1,52,000 tons Urea per annum with a fixed nitrogen content of 70,000 tons, by the total re-cycle process, has been completed by the Special Cell engaged for the purpose. The Government of India have accordingly sanctioned the setting up of a fertilizer plant at Neyveli subject to adequate credit facilities becoming available for the foreign exchange requirements of the scheme. Tender specifications are under preparation.

The first batch of 100 apprentices has been selected for training in the Sindri Fertilizers and Chemicals Limited, and if necessary, at the Fertilizers and Chemicals (Travancore) Ltd., Alwaye, for employment in the Fertilizer factory as chargemen, operators etc.

Scheme for Briquetting and Carbonisation

The pilot briquetting and carbonising plant, procured under the T.C.M. Aid for conducting tests on the Neyveli lignite, have arrived at Neyveli. The erection of sheds to accommodate the Plant is in progress. Experiments on the pilot plant are expected to start early in May, 1958 by when the plant is expected to be ready.

General

Out of total 26,750 acres of land to be acquired for the mines, factories and the township, 4,023 acres have been acquired upto December, 1957. A further area of 4,200 acres of land is expected to be acquired during 1958-59.

The Chief Town Planner of the Corporation has prepared a master plan for the Neyveli township. The Chief Architect of the Project has prepared designs for different types of building to be constructed in the township. These designs have been approved. The construction of residential and non-residential buildings valued at Rs. 1 crore is proposed to be undertaken in the new township during 1958-59. Arrangements are also in hand for the procurement of a brick manufacturing plant.

A railway siding for new township with a total length of about 4 miles at a cost of Rs. 16.25 lakhs, is also under construction.

To rehabilitate the persons who will be displaced by the acquisition of lands for the project, the Madras Government placed at the disposal of the Corporation, about 11,600 acres of forest lands, for allotment to the displaced persons after clearance. Out of this, 1,927 acres had been cleared by the Corporation by the end of December, 1957. Further clearance is in progress. Every displaced person, whose lands have been acquired, will be allotted free of cost, lands equal in extent to that acquired from him, subject to a ceiling of two acres. This will be in addition to the compensation that will be paid to him for the lands and structures acquired from him. The displaced persons are permitted to take all useful building materials from their old houses in the acquired area, free of cost, provided they remove such materials within a fixed period. The displaced persons are also given free transport for shifting the materials from the acquired site to the new site where they will be rehabilitated.

To relieve the shortage of accommodation for the staff, 200 workmen hutments and 500 Mechanics quarters are being constructed near the present Neyveli village. The Corporation has provided an elementary and a middle school in the colony for the benefit of the children of the Corporation staff. A modest temporary project hospital, with provision for 8 beds, has been constructed in the temporary colony, to meet medical requirements. The Corporation has also provided amenities, such as a Recreation Club, Employees' Co-operative Stores etc. for the benefit of the staff.

In order to enable senior officers of the project to study and obtain first hand knowledge of the equipment, organisation and operation of opencast lignite mines, thermal power stations and chemical plants based on lignite, it was decided to accept the generous offer of the West German Government to bear the cost of sending four teams of officers of the Corporation to West Germany. The opportunity was availed of to arrange for the team to spend a few weeks in East Germany and the U.K. for similar study. The Managing Director and the other teams have returned after the aforesaid study tour abroad of about two months each. The Superintending Engineer (Mines) was in the U.S.A. for a period of three months, under the T.C.M. training programme, and later for 6 weeks in West and East Germany studying the planning and operation of lignite mines.

Under the contract with Messrs L.M.G. for the supply of specialised mining machinery and with the assistance of the Government of West Germany, two Electrical Engineers and two Mechanical Engineers were sent to Germany for training for a period of three months in the design, operation and maintenance of Bucket Wheel Excavators and Slewable Spreaders.

The first financial year of the Corporation has been fixed as the period between 14-11-1956 upto 31-7-1957. The annual report of the Corporation for its first financial year is under preparation, in connection with the first General Meeting.

(*Based on the Report of the Ministry of Steel, Mines and Fuel, Government of India*, 1957-58)

Flow-Net: Its Construction and Application

By R. M. ADVANI & ALAM SINGH

The study of the natural flow of water through soil is of vital importance to an engineer, in as much as it helps to determine (*i*) the amount of seepage or leakage below or through a dam or other hydraulic structures, (*ii*) the distribution of uplift pressures on the base of the structure, (*iii*) the exit gradient and hence stability of the structure against undermining. These and other similar seepage problems can be conveniently studied with the help of the 'flow net' which provides a pictorial representation of the pattern of flow and the dissipation of the hydraulic head or driving force that causes the flow.

Since the literature available on this subject is scattered over a number of publications, attempt has been made in this article to outline the applications of flow net and also to give the various methods of its construction in a consolidated form for the benefit of those who have to deal with such problems very frequently.

The Laplace Equation

Assuming that the flow of water through soil follows Darcy's law, and the soil consists of relatively incompressible material, the following relation can be obtained when the flow is two-dimensional, that is, when it occurs only along the x-axis and z-axis (in the plane of the paper, Fig. 1) and not in the y-axis (perpendicular to the paper). (*see later for figures*)

$$\frac{\delta^2 \Phi}{\delta x^2} + \frac{\delta^2 \Phi}{\delta z^2} = 0 \qquad (1)$$

Here Φ (=kh) is known as the velocity potential, 'k' is the Darcy's coefficient of permeability and 'h' is the hydraulic head causing flow.

The above expression is known as the 'Laplace's equation.' Graphically, this equation can be represented by two sets of curves intersecting each other at right angles. The curves of one set are called 'equipotential lines' and that of the other set as 'flow lines.' An equipotential line may be defined as a line passing through points of equal head and can thus be thought of as a potential contour. The flow line is a line along which the water particles travel. These two sets of curves constitute a 'flow net.'

Construction of Flow Nets

There are several methods by which a flow net, that is, the equipotential lines and flow lines for seepage through an earth mass, can be constructed. Among these are :

1. Analytical method.
2. Experimental methods :
   (*i*) Electrical analogy ;
   (*ii*) Sand models ;
   (*iii*) Capillary flow analogy ;
   (*iv*) Membrane analogy
3. Graphical method.

Analytical method

In a few relatively simple cases the boundary conditions may be expressed by equations, and solutions may be obtained by mathematical procedure. The analytical method, though rigorously precise, is not universally applicable, because the number of known functions on which it depends is limited. Moreover, except in a few elementary cases, the analytical method lies beyond the mathematices of the routine design offices. A somewhat simpler analytical approach would be to adopt the 'method of relaxation' (Ref. 4) which can easily give the numerical solution of the Laplace equation when the boundary conditions are known. The soil stratum through which flow occurs is covered with a square grid (a network of squares). For a typical node of this grid, the Laplace equation (1) can be expressed in the finite difference approximation form by the relation :

$$\Phi_1 + \Phi_2 + \Phi_3 + \Phi_4 - 4\Phi_0 = 0 \qquad (2)$$

and this relation holds for every node in the grid. Some trial values of 'Φ' are assumed for each node, and since these values are not likely to be correct, the amount by which they fail to satisfy the relation (2) is known as the 'residual (F) or the residual equation for each node becomes

$$F_0 = \Phi_1 + \Phi_2 + \Phi_3 + \Phi_4 - 4\Phi_0 \qquad (3)$$

The residuals obtained at nodal points after substituting the assumed values of 'Φ' are liquidated (or relaxed as it is sometimes called) by the use of the 'relaxation pattern'. The final values of 'Φ' so obtained after liquidating the residuals indicate the directions of the equipotential lines and the flow lines can be drawn normal to the equipotential lines.

Experimental methods

Electrical analogy method—Pavlovsky in Russia was the first to suggest an electro-hydrodynamical analogy for the solution of seepage problems as applied to weirs and dams. The principle on which electrical analogy model studies for subsoil flow are based is that the flow of water through the permeable strata given by the well known Darcy's law viz. $q=k\frac{h}{L}A$ resembles the flow of electricity through conductors given by the so called Ohm's law viz. $I=K\frac{E}{L}a$, the corresponding quantities in the two systems being:

Flow of water through permeable soil	*Flow of electricity through conductors*
(i) q= unit discharge	I= intensity of current
(ii) h= loss of head through a certain reach	E = potential drop between two points
(iii) L= length of reach or length of path of percolation	L = length of path of current i. e the length of the conductor
(iv) A= corss-sectional area through which flow occurs	a = cross-sectional area
(v) k= co-efficient of permeability	K = co-efficient of conductivity

Thus with the help of electrical analogy models, if equipotential lines are drawn, they would correspond to the lines of equal pressure and the flow lines may be drawn in the similar way by suitably altering the current or by drawing free hand lines normal to the equipotential lines.

Sand models or seepage models—These models are usually the sectional models constructed in glass flumes to find out the lines of seepage through or underneath the hydraulic structure. The seepage lines through the model can be reproduced by injecting coloured liquid like anniline dye and observing the streak lines through the model. It may, however, be mentioned here that the sand used in the model should be clear and white and usually artificial sand from quartz is used to observe the streak lines properly. The pressures can be found out by means of piezometric tubes and the lines of equal pressures may thus be drawn. In this way the flow net is constructed.

Capillary flow analogy method—Capillary flow between two closely spaced parallel plates follows a law analogous to two-dimensional flow through soils. The model consists of two small tanks interconnected through two parallel glass plates with a capillary space between them. A solid model of the hydraulic structure is sandwiched between the two glass plates. Water flows from one tank to the other through the capillary gap past the model due to the differential head. Under steady flow conditions a dye may be introduced so as to clearly demarkate the lines of flow. Having drawn the stream lines in this manner, the equipotential lines can be easily drawn as an orthogonal set of curves.

Membrance analogy method—The infinitesimal transverse deflection 'ω' of a uniformly stretched memberance is governed by the Laplace's equation

$$\nabla^2\omega=0$$

Thus the transverse deflection 'ω' of the memberance corresponds to the pressure function 'Φ' in seepage flow.

The solution therefore consists in determining experimentally the actual deflections of a real membrane. The deflections are measured by a micrometer needle. The needle is supported on a travelling bar which itself is carried on two parallel guides fixed to supports at the end. The equipotential lines will have equal depressions below the travelling bar.

Graphical method of flow net construction

The graphical method is in general the quickest, the most practical and the most commonly used method for constructing a flow net, although at the same time the significance of the analytical approach cannot be over-looked as it furnishes the theoretical background required for developing and grasping the graphical methods. The graphical method was first given by Forchheimer and this method, depending on the conditions of the problem, takes either the form of an entirely independent, self contained solution, or is used as an auxiliary method for interpreting or interpolating the results obtained by means of model tests.

Forchhimer's method—Let AB, CD, EF and GH (Fig. 2) be the flow lines representing the paths taken by water while passing through soil under a given hydraulic head. Along each of the flow lines there will be a continuous loss of head corresponding to the drop in potential required to sustain the flow. If the points of equal potential on adjacent flow lines are joined, 'equipotential lines' are obtained. The dotted lines AG, ag, a_1g_1 .....in Fig. 2. thus represent a series of equipotential lines or lines of constant head. The equipotential lines intersect the flow lines at right angles; for if it were taken that a flow line cuts an equipotential line obliquely, the flow could be resolved into two components, one parallel to the equipotential line and the other at right angles to it. But there could be no flow parallel to the equipotential line as there is no drop of head along it; hence the resolved part of flow along it must be zero, and this can only happen when the flow line is perpendicular to the equipotential line. The strip located between two adjacent flow lines is called a 'flow channel', and every section of a

flow channel located between two equipotential lines is known as a 'field'.

Consider the fields aa_1c_1c, $a_6a_7c_7c_6$ and $e_6e_7g_7g_6$. Let l, b; l′, b′ & l_1, b_1 represent their respective lengths (dimensions along the flow line) and widths (dimensions along the equipotential line), and let the width perpendicular to the plane of paper be taken as unity.

Therefore, the respective hydraulic gradients across the fields are:

$$i=\frac{\triangle h}{l}\ ;\ i'=\frac{\triangle h'}{l}\ \text{and}\ i_1=\frac{\triangle h_1}{l_1} \quad \ldots\ldots\ldots (4)$$

Where $\triangle h$, $\triangle h'$ and $\triangle h_1$ represent the respective drops in head across each field.

If k is Darcy's coefficient of permeability, the discharges through the fields are:

$$\triangle q = k\,\frac{\triangle h}{l}\,b\ ;\ \triangle q'=k\,\frac{\triangle h'}{l'}\,b$$

and

$$\triangle q_1= k\,\frac{\triangle h_1}{l_1}\,b_1 \qquad (5)$$

Since the fields aa_1c_1c and $a_6a_7c_7c_6$ have the same flow line boundaries, $\triangle q$ equals $\triangle q'$, and since the field $a_6a_7c_7c_6$ has the same equipotential boundaries as the field $e_6e_7g_7g_6$, $\triangle h'$ equals $\triangle h_1$. Further, if it is assumed that $\frac{b}{l}=\frac{b'}{l'}=\frac{b_1}{l_1}=$ constant, the following relationships can be obtained from the foregoing equalities.

$$\triangle q = \triangle q_1 \text{ and } \triangle h = \triangle h_1 \qquad (6)$$

Thus, it follows that if the b/l ratio is the same for all the fields, there must be the same quantity of flow through each field and the same head drop in crossing each field. Conversely, to have the same flow through each flow channel and the same potential drop between successive equipotentials all fields must have the same b/l ratio. For convenience, the b/l ratio is made equal to unity and then all the fields assume the shape of approximate squares. It was this criterion of 'approximate squares' which was first put forward by Forchheimer for constructing a flow net.

Before starting the construction of the flow net, one must examine the hydraulic boundary conditions of the problem and ascertain their effect on the shape of the flow lines. Boundary conditions may vary from problem to problem and as an illustration a simple case of seepage thorough homogeneous sand beneath the base of a concrete dam (Fig. 3) is given here. The upstream and downstream ground surfaces represent equipotential lines. The base of the dam and sides of the cut-off wall represent the uppermost flow line, and the base of the pervious stratum represent the lowest flow line. The other flow lines lie between these two, and their shapes must represent a gradual transition from one to the other. Also the flow lines are vertical where they meet the upsteam and downstream ground surfaces as these are the equipotential lines. Now the construction of the flow net can be started by first drawing several smooth curves representing the flow lines, such as one such flow line is shown in Fig. 3 Then several equipotential lines are so drawn as to interesect the flow lines at right angles and make the fields roughly square figures. The first trial flow net so obtained is carefully examined in order to detect the most conspicuous defects which are then rectified and the net is redrawn. The process of ajustment is continued until all the fields are approximate squares. The fields may now be further subdivided to get a finer flow net, and the adjustments are carried out as before.

Casagrande's suggestions (Ref. 1). The following hints are based on the suggestions given by A. Casagrande for the beginner in flow net sketching :

1. Try to absorb in mind the appearance of well-constructed flow nets and practice by reproducing them without looking at the available solution.

2. At the first attempt four or five flow channels are sufficient; in use of too many flow channels may distract the attention from the essential features.

3. Always watch the appearance of the entire flow net and do not try to adjust details before the entire flow net is approximately correct.

4. Keep in mind that all transitions are smooth having elliptical or parabolic shape. The size of the squares in each channel will change gradually.

Taylor's explicit trial method (Ref. 2)—A procedure with more explicit instructions has been given by Taylor which he claims to be of considerable value in flow net sketching and in dveloping an intuition for flow net characteristics. The outlines of the procedure are :

1. As a first step, sketch one trial flow line or one trial equipotential line adjacent to a boundary flow line or a boundary equipotential line. Often it is simpler to start with a trial flow line. The heavy line in Fig. 4 is such a trial line.

2. Starting from one side, say left, divide into approximate squares the flow channel between the trial flow line and the top boundary flow line. The first square is of irregular form and is called a singular square. In case the number of fields (squares) is not a full integer, revise the trial line until a case with an integral number of fields is obtained.

3. Extend downward the equipotential lines forming sides of the square fields, and add another row of approximate squares formed out of these extensions, then the lower boundaries of all these squares after smoothening the irregularities represent the next flow line. When this flow line has been drawn, readjust the equipotential lines, if necessary, so that all intersections are at right angles.

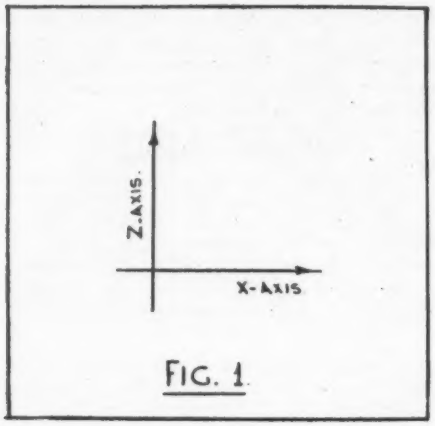


FIG. 1.

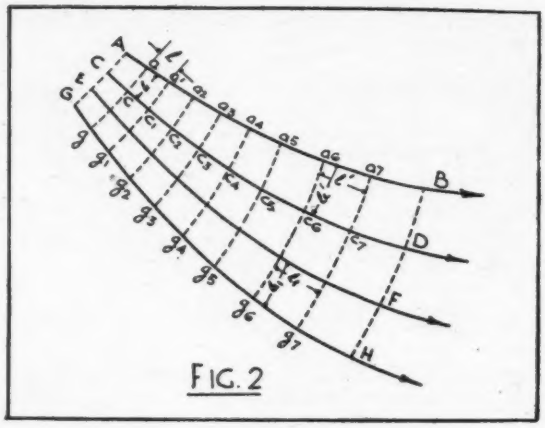


FIG. 2

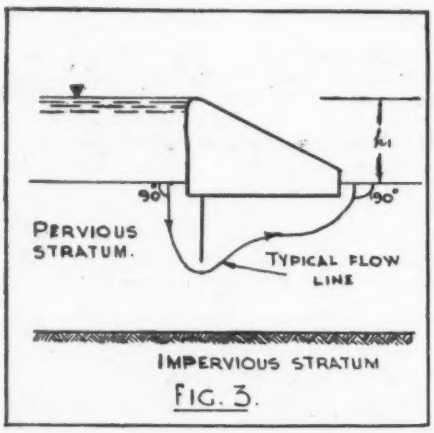


FIG. 3.

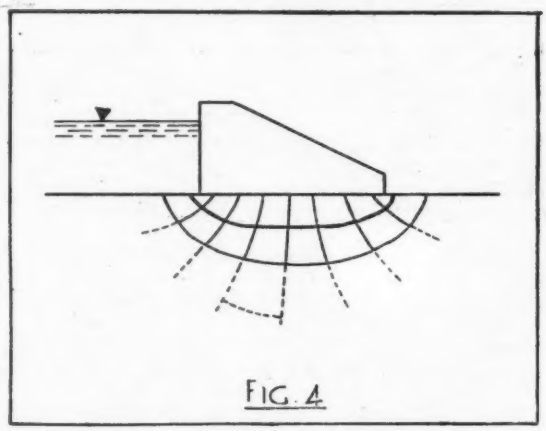


FIG. 4

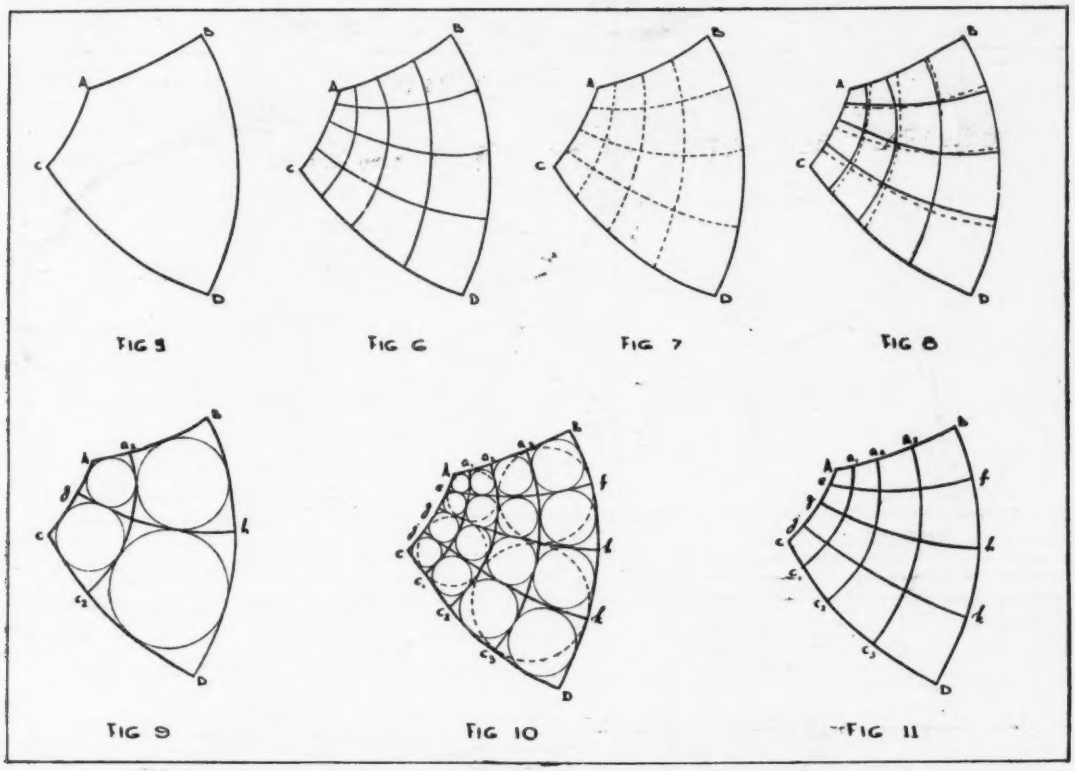
4. Continue the downward expansion as outlined in step 3, until the top of the impervious stratum if any is reached. The last flow line must coincide with the bottom boundary flow line, which serves as a check on the assumed alignment of the first trial flow line. If it does not coincide, restart with another assumed first flow line. If the permeable strata is of unlimited depth, the last flow line below some depth must be a semicircle (Fig. 4 illustrates the method of exansion of the flow net downwards).

Limitations of the Criterion of 'Approximate square'. The solution obtained by Forchheimer's method cannot be considered perfect, because the basic criterion of 'approximate square' is not rigid enough, so that there always remains a doubt as to whether the final result has been, indeed the best one. This point can be better understood with the help of Figures 5 to 8. Figure 5 represents a field ABCD to be investigated. In the field AB and CD may be supposed to represent the flow lines and AC and BD the equipotential lines. Satisfying the condition of 'approximate square', a great number of flow nets can be drawn in the field under investigation. Figures 6 and 7 represent two such solutions which appear to be quite satisfactory and good. It will, however, be apparent from Fig. 8, in which the two nets are superposed, that the two nets do not coincide and instead of calling the nets satisfactory, both the nets might be termed unsatisfactory; moreover, there is no independent standard which can be used as a common basis in comparing their advantages.

Leliavsky's Criterion of 'Circle'. In order to improve the precision of Forchheimer's general solution, Leliavsky (Ref. 3) has recently developed his criterion of 'circle' from the basic concept that four curves which intersect at right angles are all tangent to a common circle and, therefore, a perfect flow net should consist of fields in each of which in should be possible to place a circle. The suggestion of placing circles is illustrated in Figures 9, 10 and 11. Fig. 9 represents the same field under investigation as in Fig. 5. First four contangent circles are placed in the field ABDC, and through the points of contact of the circles, the flow line gh and equipotential line $a_2 c_2$

are drwan. Fig. 10 represents the process of further subdivision and obtaining a finer net; while in Fig. 11 the circles are omitted, and the diagram therefore appears in its final form.

Fig. 13 represents the body wall of a weir with cut off and downstream apron founded on permeable soil of infinite depth. Circles are shown in the left half of the flow net only while they have been omitted from the right half.



It will be seen that though graphical computation can never be ideal because in carrying it out in practice pencil lines are necessarily substituted for theoretical curves, it will nevertheless be realised that there is one and only one combination of sixteen ideal tangent circles which can form a regular pattern, entirely filling the whole area enclosed by the four boundary curves AB, CD, AC & BD in Fig. 10. The circle method is therefore mathematically precise.

A few examples to illustrate the application of the circle method are given below:—

Fig. 12 represents the flow under a sheet pile fixed in a pervious strata of limited depth. Keeping in vew the hydraulic boundary conditions, a coarse flow net consisting of the flow lines AB, CD & EF and the equipotential lines ab, cd, & ef is first constructed. Further subdivision is easily obtained by drawing more lines (shown dotted in the right half only through the points of contact of the circles, thus making each bigger field to be further subdivided in to four smaller fields. If desired, circles can be placed as well in the smaller fields so obtained, and further subdivision can be carried out. Four such small circles are also shown dotted in the figure. When the final flow net has been obtained the circles can be omitted.

Fig. 14 shows the sectional elevation of the regulator which was designed on the basis of "Bligh" theory by Alam Singh when he was working and undergoing training in Sarda Power Channel Construction Dividsion, Irrigation Department U.P. in 1952. The regulator was proposed to be constructed at mile 1.7.569 of the Power channel. The comparison of uplift pressures formerly calculated by Bligh theory with those calculated now from the flow net is given in problem 4. It is assumed that the pervious strata extends to a great depth. The flow net is presented in the final form after omitting the circles.

Flow net for anisotropic soil—All of the foregiong discussion of flow nets refers to flow of water through isotropic soils, that is, soils in which the coefficient of permeability is the same in all directions. However, frequently the soil deposits are more permeable in one direction than in the other direction. (Generally the horizontal permeability k_h is more than the vertical permeability k_v. In order to construct the flow net for an anisotropic soil stratum of this type, the drawing is first made to a distorted scale, the horizontal dimensions being reduced by the factor $\sqrt{\frac{kv}{kh}}$ in relation to

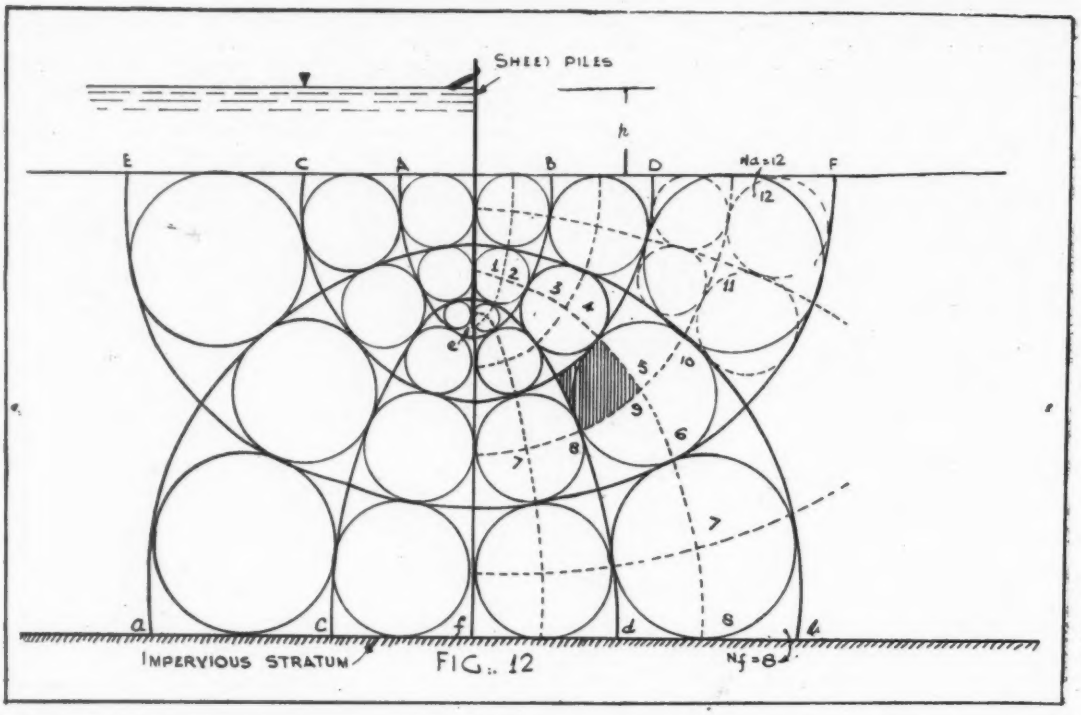


FIG. 12

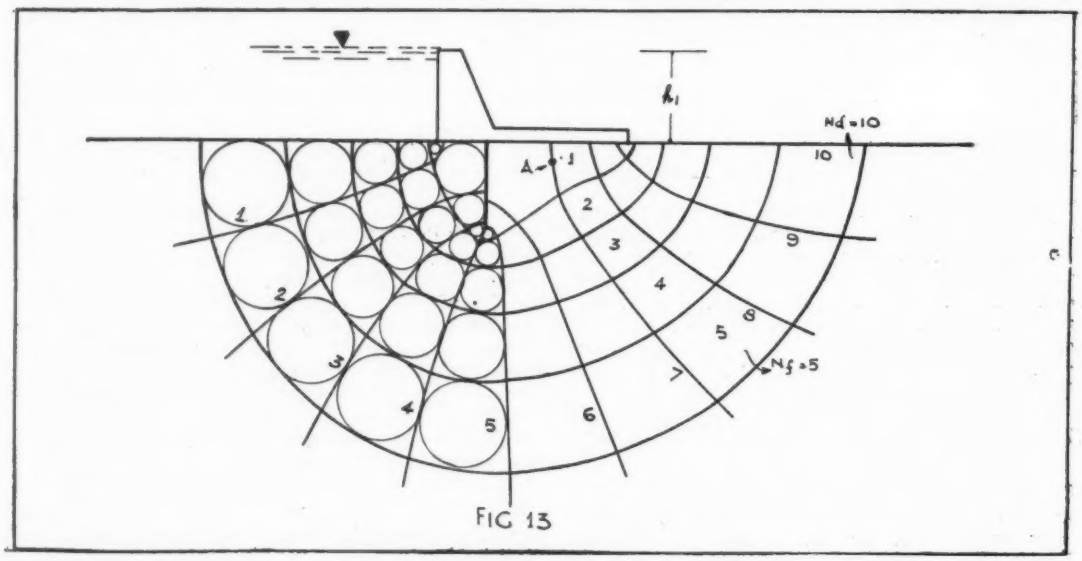


FIG 13

the vertical dimensions. For this distorted section the flow net can be constructed as if the permeable stratum were isotropic. After the construction is finished, the final flow net is obtained by re-transforming all the dimensions, including those of the flow net to the natural scale. The flow net thus obtained represents the actual equipotential and flow lines for the anisotropic soil, but the two sets of lines do no longer intersect at right angles.

Application of Flow Net

Determination of seepage

Let N_d be the total number of potential drops in a flow net and let h_1 be the hydraulic head causing the flow. Therefore, the potential drop in each field is

$$\Delta h = \frac{h_1}{N_d} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

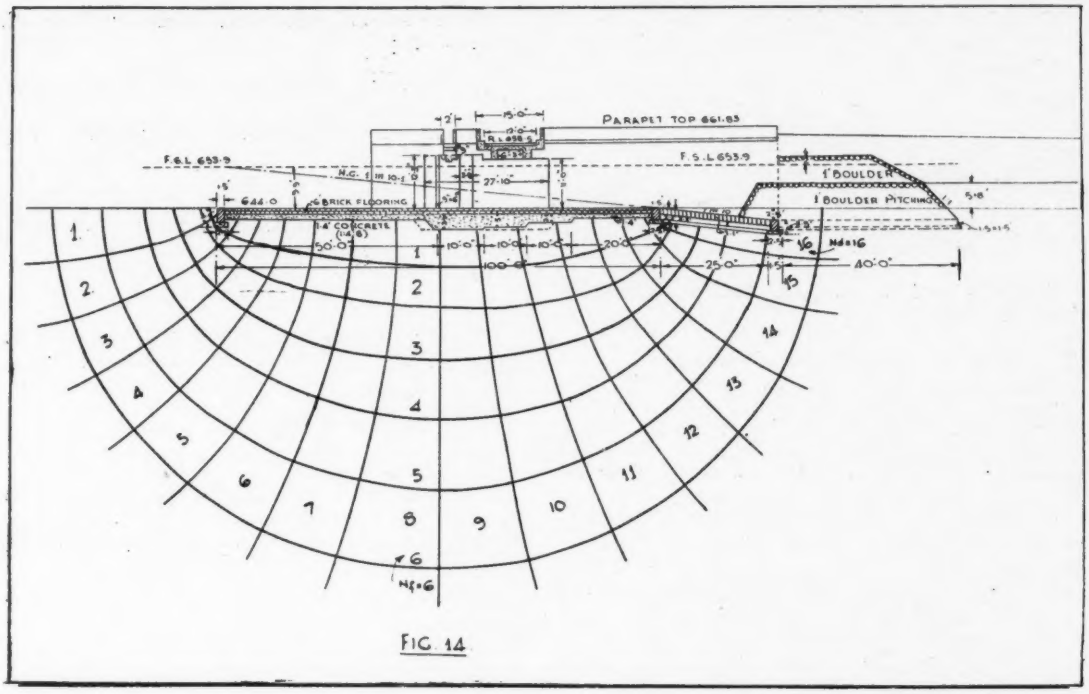


FIG. 14

Considering a typical field indicated by the shaded area in Fig. 12, let l be the average length and width (the field being an approximate square) of the field. the hydraulic gradient across the field is

$$i=\frac{\triangle h}{l}$$

and the discharge through the field and thus through the flow channel no. 5 per unit width of the sheet piles is

$$\triangle q=k\,\frac{\triangle h}{l}\,l=k.\ \triangle h$$

Where k is the Darcy's coefficient of permeability

Or $$\triangle q=k\,\frac{h_1}{N_d}\qquad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

If N_f is the total number of flow channels, the total seepage q per unit width of sheet piles and per unit of time is

$$q=k\ h_1\,\frac{N_f}{N_d}\qquad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

By means of equation (9) the seepage can be computed readily, after the flow net has been constructed. However, when the soil is anisotropic the value of the coefficient of permeability to be used in equation (9) is given by

$$k'=\sqrt{k_h\times k_v}\qquad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

Problem 1. The soil stratum shown in Fig. 12 has a permeability in every direction of 3×10^{-3} cm per sec. The head h_1 is 10 ft. Calculate the amount of water that will percolate per second, per unit width of the sheet-piles.

Solution : From the flow new $N_f=8$ and $N_d=12$ (The dotted flow and equipotential lines extend to the left half of the diagram as well, although they are not shown so in the Fig. 12) Using equation (9)

$$q=k\,h_1\,\frac{N_f}{N_d}$$

$$=\frac{3\times10^{-3}}{30{\cdot}5}\times10\times\frac{8}{12}\text{ cu. ft. per sec.}$$

$$=6.55\text{ cu. ft. per sec.}$$

The validity of the flow net procedure for calculating the seepage can be demonstrated by comparing the results obtained by the use equations (9) with the result obtained by use of Darcy's relation q=ki A when both of them are applied to flow of water in a constant-head permeameter as shown in Fig. 15.

It is a simple case of rectilinear seepage though a mass of soil cross section of which is assumed to be rectangular. In this case all the flow lines are parallel to each other and also parallel to the longitudinal axis of the soil mass. The equipotential lines are all vertical.

Problem 2. Assume that the soil mass for which flow net is shown in Fig.15 is 10 cm wide, 10 cm. high and 20 cm. long, and the water is flowing under a head of 40 cm. Determine the discharge per unit time, it $k=2.5\times10^{2}$ cm. per sec.

Solution: (a) $N_f=3$, $N_d=6$; From equation (9) discharge per unit width is given by $kh_1\,\frac{N_f}{N_d}$

Therefore, total discharge

$$q' = kh_1 \frac{N_f}{N_d} \times 10$$
$$= 2.5 \times 10^{-2} \times 40 \times \tfrac{5}{8} \times 10$$
$$= 5 \text{ cu. cm. p.r sec.}$$

(b) By Darcy's law
$q' = k\ i\ A$
$= 2.5 \times 10^{-2} \times \frac{4.0}{1.0} \times 10 \times 10$
$= 5$ cu. cm. per sec.

It will be seen that the same result is obtained by both the methods.

Determination of excess hydrostatic pressure

Once the flow net has been constructed, excess hydrostatic pressure at any point located within the flow net can be calculated. The excess hydrostatic pressure is due to the hydraulic head which gets gradually dissipated as water percolates from the upstream entry to the down stream exit. If h_1 is the hydraulic head i. e. the difference between the downstream and upstream water levels and $\triangle h$ is the potential drop in each field, then the excess hydrostatic pressure at any point located after 'n' potential drops within the flow net is given by

$$u = (h_1 - n.\ \triangle h)\ \gamma_w \qquad (11)$$

where γ_w = unit weight of water

and $\triangle h = \frac{h_1}{N_d}$; N_d being total number of potential drops.

Problem 3. Find out the excess hydrostatic pressure (uplift pressure) at point A in Fig. 13, if h_1 is 15 feet,

Solution : From the flow net, $N_d = 10$

Therefore $\triangle h = \frac{15}{10}$ ft.

Since point A is located on the right hand boundary of the 7th equipotential drop, excess hydrostatic pressure using equation (11) is given by

$$u = (15 - 7 \times \tfrac{15}{10})\ 62.5 \text{ lbs. per sq. ft.}$$

Or $u = 15 - 10.5 = 4.5$ ft. of head in excess of that at tail-water level.

Problem 4. Estimate the uplift pressure (in excess of that at tail-water level) in feet of water on the downstream floor of the regulator shown in Fig. 14, assuming the height of water on the upstream side as 9.9 feet and no water on the downstream side.

Solution : $h_1 = 9.9$. ft., $N_d = 16$

Therefore, $\triangle h = \frac{9.9}{16}$ ft.

(i) Pressure at the midpoint of the 9th potential drop

$$u_1 = 9.9 - 8.5 \frac{9.9}{16} = 4.65 \text{ ft.}$$

(ii) Pressure at right hand boundary of the 9th potential drop

$$u_2 = 9.9 - 9 \frac{9.9}{16} = 4.34 \text{ ft.}$$

(iii) Pressure at the end of 10th potential drop

$$u_3 = 9.9 - 10 \frac{9.9}{16} = 3.70 \text{ ft.}$$

(iv) Pressure at the end of the 11th potential drop

$$u_4 = 9.9 - 11 \frac{9.9}{16} = 3.15 \text{ ft.}$$

Similarly pressures at the ends of 12th, 13th and 14th equipotential drops are calculated and given by

$u_5 = 2.58$ ft.
$u_6 = 1.85$ ft
$u_7 = 1.23$ ft.

It is of interest to compare the uplift pressures so calculated with the pressures calculated on the basis of Bligh theory for the same points, the comparison being given in the form of a table below:—

Uplift pressure (ft. of water) in excess of that at tailwater level	U_1	U_2	U_3	U_4	U_5	U_6	U_7
Bligh Theory	4.10	3.60	3.00	2.00	1.20	0.60	0.25
Flow net	4·65	4.34	3.70	3.15	2.58	1.85	1.23

It will be seen that the loss of head does not take place uniformly in direct proportion to creep length as stated by Bligh, but is dependent on the whole geometry of the figure and is quicker where the equipotential lines are closer and vice-versa

Determination of exit gradient

The rate of loss of head or the gradinet at exit is determined from the fields at the exit end. If '$\triangle h$' is the loss of head between two succesive equipotential lines and 'a' the istance apart at any place between the last two equipotential lines, the exit gradient at that place is $\frac{\triangle h}{a}$.

For a conservative design, this steepest value of the exit gradient should be well below the critical gradient given by the expression : $(1-n)(G-1)$, for if critical gradient is reached the failure of undermining is imminent. The average value of G (specific gravity) for most river sands is 2.65 and an average value of porosity (n) is 0.4; the value of critical gradient is, therefore, $(1-0.4)(2.65-1) = 0.99$ or very nearly 1.0 on the average. The actual gradient at the exit determined from flow net should be much less, say 1/4 to 1/6 depending on the requirement of safety.

Thus the safety against undermining is not obtained by a flat average gradient $= \frac{\text{seepage head}}{\text{total creep length}}$ as ad-

vance by Bligh but by an exit gradient well below the critical.

Seepage through earthen dams (*Ref.* 5)

It is necessary to predict the position of the seepage line in a proposed dam section to

(i) ensure that it does not cut the downstream face of the dam and thereby produce softening or sloughing of the toe;

(ii) obtain the dividing line between moist or dry, and submerged soil in the dam section and carry out the stability computations accordingly ;

(iii) obtain the top boundary line for drawing the flow net for quantity of seepage computations.

It has been established that the flow net through an earthen embankment of homogeneous material will consist of two sets of 'confocal parabolas' provided the proper boundary conditions are satisfied. A hypothetical section of an earthen dam which satisfies these conditions is shown in Fig. 16.

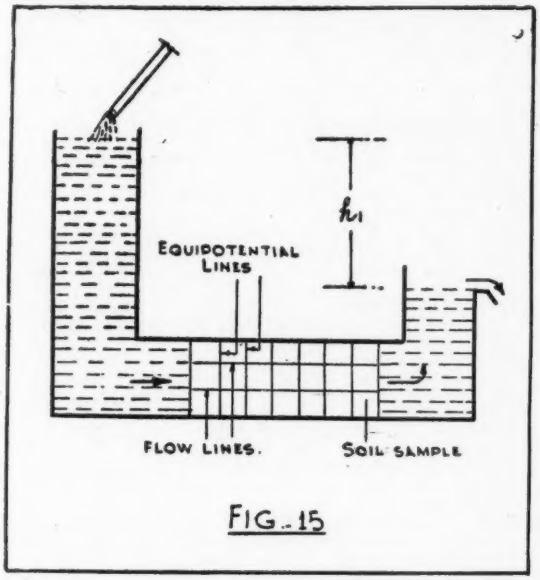


FIG. 15

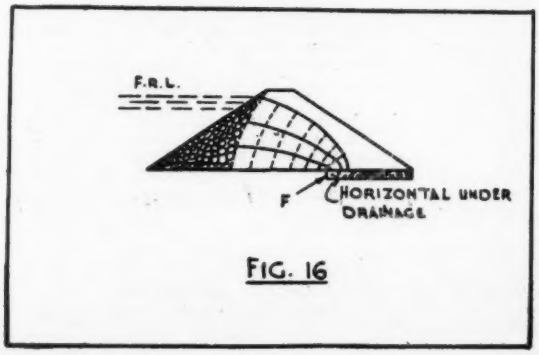


FIG. 16

In this section a horizontal underdrainage is provided and in addition the upstream face has got a highly pervious rock fill of a parabolic shape through which the loss of head is negligible. For a section like this the flow lines are represented by parabolas shown firm in the figure and equipotential lines by parabolas shown dotted. Both these sets of parabolas have their focus at the point F, where the horizontal drainage begains.

For a practical case the following characteristics of the seepage line may be noted.

1. At its starting point, the top flow line must be normal to the upstream slope which is an equipotential surface.

2. Since the pressure all along this line is atmospheric the only change in head along this line is that due to drop in elevation. Hence successive equipotential lines will meet the top flow line at equivertical intervals.

3. Into a filter or a rock filled toe, the seepage line would tend to merge vertically.

4. For an earth dam composed of homogeneous materials, the seepage line will cut the downstream face above the base of the dam unless special drainage measures are adopted. The position of this line depends only on the geometry of the cross-section of the dam.

5. The focus of the base parabola lies at break out point of the bottom flow line.

6. The presence of pervious stratum below the dam does not influence the position of the seepage line. If, however, a cut-off is provided through the entire depth of the pervious stratum upto the impervious stratum below, the portion of the pervious stratum downstream of the cut-off will act as a drain and the seepage line will be drawn into the dam without the provision of a rock or horizontal underdrainage.

7. For a dam with non-homogeneous section, with an impervious core in the centre, because of the great disparity between the permeabilities of the outer shell and the central core, the effect of the outer shells can be neglected altogether. The focus of the base parabola is located at the downstream toe of the core. The base parabola and hence the seepage line is sketched for the core alone neglecting the presence of the shells. The seepage line is assumed to be practically horizontal through the upstream shell; the downstream shell acts as a drain and is saturated to just enough depth to carry the seepage discharge passing through the core.

Conclusion

In this paper attempt has been made to describe briefly the various methods of construction of flow nets as also their application for the study of seepage problems. It has been shown that the graphical method of flow net construction is the quickest and the simplest method. Further it has been shown that once the flow net for a given problem has been obtained, all the effects of seepage such as rate of percolation,

uplift pressures, safety of structure against undermining etc. can be easily obtained from it. The application of flow nets for earthen dam problems has been only briefly indicated for want of space. The authors, however, hope to furnish this information in the form of a separate paper in the near future.

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Corrigenda

Page 2—6th line from bottom after "for the turbines" read "Also, the temperature difference between the warm surface layers in tropical seas and the cold water of the depth can be utilised in a thermodynamic cycle".

Page 9 & 10—Fig. 2 should be marked Fig. 3, and Fig. 3 should be marked Fig. 2.

Institution of Engineers (India)

The Institution of Engineers (India), which is the most representative professional organisation of engineers of India, has a busy programme abroad this year and the President of the Institution for this year, Mr. D.P.R. Cassad is leading its delegation to the various International Conferences. Some of these are mentioned below.

World Power Conference—Sectional Meeting

The next Sectional Meeting of the World Power Conference will be held in Montreal from September 6—15. The time of this Meeting will be 'Economic Trends in the Production, Transport and Utilisation of Fuel and Energy'. Papers have been contributed from India to the Meeting.

The delegation from the Indian National Committee will consist of the President (Leader), Shri E. A. Nadirshah (a Past President of the Institution and a Past-President of the Indian National Committee for the World Power Conference), Shri M. N. Bapat (Tata Hydro-Electric Companies), and Prof. M. V. Deshpande (Visiting Professor of Electrical Engineering University of Illinois, U.S.A.).

The President and Shri Nadirshah will also represent the Indian National Committee at the 1958 Meeting of the International Executive Council of the World Power Conference to be held in Montreal on 6th September.

The President will further take the Chair of Technical Session A3, when the subject for discussion will be 'Production of Hydraulic Energy'.

At the terminational of the Sectional Meeting, the President and Shri Nadirshah will take part in one of of the Study Tours which will take them. amongst other things, to the St. Lawrence Seaway Project, one of the greatest engineering projects in the history of the world.

Sixth International Commission on Large Dams

At the conclusion of the above Study Tour, the President and Shri. Nadirshah will attend the Sixth Congress on Large Dams which will be held in New York from 15th to 20th September, 1958. The Indian National Committee for the International Commission on Large Dams is the Central Board of Irrigation and Power, Government of India.

At the conclusion of the Sixth Congress, the President and Shri Nadirshah will take part in a Study Tour which includes the great Grand Coulee Dam.

Press conference addressed by Mr. D. P. R. Cassad, L to R : Mr. R. M. Patri, President Cassad, Mr. B. Seshadri, Secretary, Mr. S. Sarwal, Asst. Secretary.

President D.P.R. Cassad talking with Mr. K.K. Sinha, Editor of the Journal and Mr. P. K. Menon the Managing Editor (Centre)

During his stay in the United States and Canada, the President will also pay official visits to sister Institutions in the two countries, particularly to The Engineering Institute of Canda, in Montreal, and the American Society of Civil Engineers in New York.

Fiftieth Anniversary Conference of the Institution of Structural Engineers, London.

The Institution of Structural Engineers, London. are holding their Golden Jubilee Celebrations between the 7th to 10th October, 1958. The President has accepted the invitation of that Institution to attend the Conference, and will officially represent the Institution of Engineers (India) at the Celebrations.

World Petroleum Congress

The Institution has also acted as the Indian National Committee for the World Petroleum Congress since 1950. The Sixth Congress will be held in New York in May-June, 1959, and preparations for participation are now proceeding including the submission of papers.

Membership

The membership of the Institute today exceeds 19,000 and comprises nine grades. At the top of the list of Honorary Members are the President and the Prime Minister of India. There are only two Honorary Life Members, Sir Mokshagundam Visveswaraya and Dr. H. J. Bhabha. Corporate Members alone number over 6,500 and Students nearly 12,000.

The membership embraces all branches of engineering including Civil, Mechanical, Electrical, Chemical, Metallurgical, Mining Aeronautiocal Telecommunication, etc.

Technical Sections and Groups

The techincal activities of the Institution are mainly carried out through its four Sections and seven Groups. The four Sections are Civil, Mechanical, Electrical and General, and the seven Groups, Prestressed Concrete, Public Health Engineering, Aeronautics, Telecommunication, Chemical Engineering, Mining and metallurgy, and Nuclear Engineering.

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Durgapur Thermal Power Station and the Coke-Oven Gas Grid

Future Demand

It has already been mentioned that the Central Water and Power Commission had recently undertaken a detailed load survey in the Damodar Valley area to determine the probable growth of load and the combined power position up to 1970-71 According to their findings, there would be a shortage of power to the extent of 150, 600 and 1,000 mW. in 1960-61, 1965-66 and 1970-71 respectively. In the above study the increase of CESC's load had been estimated on the basis of 5 per cent. per annum instead of a realistic figure to 8 of 10 per cent. This will account for 30-40 mW. additional power by 1960-61 with more deficit by the same amcunt. In case railway electrification be taken as a separate issue, shortage of power for other reasons would remain almost the same as stated above. The West Bengal's portion out of that deficit amounted to 120, 300 and 600 mw. in 1960-61, 1965-66 and 1970-71 respectively. This has resulted due to rapid growth of load in industrial area from Durgapur to Calcutta. Recently CESC being unable to cope with the increasing demand, handed over some part of Howrah area, which was until now being supplied by them under section 27 of I.E. Act, to the West Bengal State Electricity Board for distribution. The other industrial areas, e.g., Bouria and Bandel, are badly in need of power to the extent of 50 mW. for industrial development. The same being outside the licensed area of CESC as well as DVC now rest on the Board for supply. All the above indicate that unless immediate steps are taken to augment the power position, the industrial development to the above areas would be completely paralysed.

As time is a very important factor, the shortage of power must be met by (*i*) augmentation of the existing thermal station and (*ii*) installation of additional thermal power station on appropriate location.

For immediate relief of about 100 mW. for West Bengal (outside the licensed area of DVC and CESC) by 1960-61, it is the only logical course to augment the capacity of the Durgapur Thermal Station, which is in an advanced stage of completion, by two more sets of 60 mW. each and building a new D/C 132 kV. double circuit transmission line between Durgapur and Belmuri, a distance of about 60 miles. In connection with supply of power to the Eastern Railway near Calcutta, the railway authorities have already recommended construction of a circular grid by the State Electricity Board connecting Belmuri with Bandel, Mulajore, Sonarpur and Howrah sub-stations at a cost of Rs. 2¼ crore approximately. The installation of the two additional sets at Durgapur and the construction of transmission line between Durgapur and Belmuri will enable supply of power through this circular grid for meeting the expanding needs of the West Bengal State Electricity Board at Bandel, etc., and the railways on the east of the river Hooghly.

The Durgapur Power Station of the State Government has been so designed that it can be expanded at minimum cost. The railway siding, arrangements for handling coal, supply of cooling water and many other facilities, which have already been provided will enable completion of this extension at a comparatively low cost by 1961 provided the work is taken up immediately. The availability of low grade coal recently discovered very close to Durgapur will facilitate smooth working of this Power Station as the transport problem will be solved to a great extent. It is considered that no other Power Station can be more favourably located than the one at Durgapur for catering to the above load.

The above arrangement would also indirectly help DVC to supply CESC and other industries en route to the full extent as committed by the Corporation by agreement. As Corporation's existing transmission system up to Calcutta will be overloaded very soon, builing up of an additional transmission system from Durgapur to Calcutta is unavoidable.

The Right Approach

The Second Five Year Plan unfortunately laid stress on industrial development without adequate emphasis on agricultural production. This is an old story for which the Ministers for Food, both at the Centre as well as in the States, are not alone responsible. The responsibility belongs to the leadership of the Government as a whole and also to the leading Opposition parties who have been stressing on rapid industrial development without caring to build the economic base for such a development, namely, a relatively prosperous agrarian economy. Now we are in the midst of the Second Five Year Plan and have begun to feel the full impact of the industrial development without necessary resources. Agrarian production is not keeping pace with the statistical estimates. Food crisis and rise in prices are showing up in many parts of the country. The position of the Ministers in charge of food are threatened everywhere. But are these not the inescapable results of faulty planning ?

Fortunately, however, the country is trying to draw its attention towards the problems of agriculture once again. The Planning Commission in a paper submitted to the National Development Council in January 1958, pointed out that the results of agricultural production from 1949 to 1957 "did not reflect adequately the large outlays incurred during recent years on agricultural production programmes". Among the reasons for this trend given are :

(1) There had not been enough concentration of effort on increasing yields per acre in irrigated areas and in areas with assured rainfall ;

(2) Progress in the utilisation of the irrigation potential created through major and medium irrigation schemes had not been satisfactory ;

(3) Minor irrigation, which was intended to be a programme undertaken mainly with popular support and making the maximum use of local manpower resources and local possibilities of irrigation, had tended to develop into a departmental programme with insufficient public participation. In national extension service and community project areas the provisions for minor irrigation had not been adequately utilised and minor irrigation programmes in these areas needed to be co-ordinated much more fully with the Agriculture Departments' minor irrigation programmes ;

(4) The maintenance of a large proportion of local minor irrigation works, specially tanks, was in an unsatisfactory state;

(5) The implementation of the programme for setting up seedfarms had to be expedited. It was specially important that multiplication of improved seed should be carried as early as possible to the village level and every village should have a plan for multiplication of seed to meet its requirements;

(6) On account of the foreign exchange shortage, supplies of chemical fertilisers were bound to fall short of the demand which was itself increasing. It was essential that the gap should be filled through greater efforts in the direction of green manures and organic manures and other local manurial resources,

(7) The crux of the problem of reaching every village and every family through the community development programme lay in the building up of village institutions—the panchayat and the co-operative—for undertaking village planning.

(8) It was essential to link credit with agricultural production programmes. This had to be done essentially at the village level.

Following the meeting of the National Development Council Standing Committee in January, the Programme Administration Advisors went into the problem of utilisation of irrigation facilities in the various States and made some specific recommendations for further action. Some of these are:

(1) Construction of field channels and other ancillary works needed for irrigation.

(2) Speeding up localisation areas to be irrigated from certain projects;

(3) Organisation of demonstration plots, introduction of appropriate patterns and guidance in irrigated cultivation;

(4) Introduction of legislation for making a compulsory charge from all persons whose lands are eligible for irrigation supplies;

(5) Arrangements for seed multiplication at the village level;

(6) Intensification of the campaign for green manuring; and

(7) Expediting the production of improved seed on farms for which land has already been obtained and speeding up the entire programme for the setting up of seed farming.

Similarly it has been found that the agricultural

aspects of the Community Development programme has remained unfulfilled.

Since these reports have been published, the Government has been organising a number of regional conferences to investigate ways and means of improving agricultural production. One such conference was the Regional Minor Irrigation Conference held in Calcutta recently. In this conference it was pointed out that elimination of procedural delays would considerably improve the situation.

If one takes a broad perspective view of the problem, it would be evident that the whole approach to agriculture is rather inadequate. We have been so much dazzled by the perspective of industrialisation, that by and large, the importance of agriculture has been removed from our minds. The glamour of cities and giant industries has held our attention. This might have been justified provided we had enough foreign aid assured in advance. In its absence however we have to depend upon our own internal resources. And these resources are nothing else but savings from agriculture, which constitutes the most dominating part of our economy.

Now that we are beginning to realise that we cannot give up our attention from agriculture, the question has arisen as to how to increase the productivity per acre as also to increase the total acreage.

The reports amply point out that although we have been spending considerable sums of money in both large schemes like river valley projects, as well as small projects, none of these have produced the anticipated results. Now we are instituting numerous enquiries to find out why. While a microscopic examination of each aspect of the problem will expose numerous deficiencies, it is possible that by remaining engaged in doing so we may miss the wood for the trees.

Agriculture is essentially an individual-centred function. If we want prosperity in agriculture, all our efforts must be informed by this basic concept. But, are not all our efforts directed in the contrary direction today. For example the Community projects administration was planned from the top and extended throughout the country. This far-flung Governmental machinery now tends to perpetuate itself, thus coming in the way of the development of local leadership. Benevolent administration from the top does not harmonise with the growth of local initiative and enterprise. The crucial point is, *are we prepared to experiment in trusting the people and in letting them commit mistakes and learn by trial and error?* Only then will they grow in stature and personality and be able to accept responsibility for their own action or inaction.

Similarly, in the field of irrigation there is a persistent criticism that irrigation facilities are not being fully utilised. Distributaries have not been got ready in time. There is resistance to payment of water charges or betterment levy. It appears from all this as if the peasant is giving up his traditional attitude and does not need water for his crops. We are considering even to impose a compulsory levy even if he does not use the water. Is this not driving us towards a ridiculous position? If we are swimming against normal human psychology, we must begin to doubt we must be severely erring somewhere.

But is such a trend of thought justified? On the question of fuller utilisation of irrigation waters, however, the situation is not so depressing as it is made out. As Dr. K. L. Rao has recently explained elsewhere (*Bhagirath*), the irrigation potential was 5.67 m. acres at the end of March '57, while the corresponding utilisation figure is 3.91 m. acres, leaving a balance of 1.76 million acres. That is, 70% of the potential has been utilised. This is quite a satisfactory figure if we consider the fact that there is a natural lag in utilisation for several intrinsic reasons. Compared to foreign experience as well as to that of past Indian ones, the performance is indeed much better. Possibly much of the apprehension on this ground is due to lack of grasp of the dynamics of development of such projects by our politicians and legislators.

If the water is really needed in the region, then either the peasants' ignorance or some other factor must be coming in the way of fuller utilisation. Apart from the technical aspects, what then becomes important is to educate the people in terms of the real facts. Part of this education should consist in the devolution of responsibility for the maintenance of the irrigation facilities on the cultivators themselves. What we are driving at is the creation of *autonomous co-operative water districts* such as in the U. S. A. If these are planned well ahead of time and explained to the people, they will themselves undertake supervision of the excavation of distributaries, the distribution of the waters, and the collection of the water charges and levy on a self-liquidating basis. But the point is, have we ever cared to turst the people in a significant manner?

The question is of *leadership*. This cannot be provided by Government or Government Departments or by Engineers. The political and local community leaders are there. Let them bestir themselves in undertaking this educative task. We have heard long discourses on co-operatives. The time is for action. Let the leaders of the public go out to the country and tell the people to undertake the responsibilities of promoting agricultural production. The Governmental machinery can at best supplement. Let this be on an improved basis, but after all, it can only supplement the efforts by the people themselves. Let not the politicians shift the blame on to the engineers. It would be far more constructive if the former engaged themselves in going to the peasants and helping them to help themselves. That will be the right approach. Any number of technical conferences will prove of little avail in the absence of popular initiative and public leadership.

Book Review

United Nations Publications

No. 1. **Industrialisation and Production**: Bulletin no. 1.

This very useful bulletin brought out by the Bureau of Economic and Social Affairs contains some extremely thought-provoking and well documented articles such as," "Capital Intensity in Industry in under-developed countries"; "Choice and Technology in Industrial Planning" by J. Tinbergen; "Capital Intensity in Heavy Engineering Construction"; "Higher Purchase Loans for the Mechanisation of Small Industry" by J. E. Stephance, etc. The bulletin has been further made useful by including in it a selected list of books and titles on Industrialisation. It has come none too early, and will be welcomed by a very large number of specialists in under-developed countries.

No 2. **Water for Industrial Use.**

This preliminary study of Economic and Social Affairs, with the help of Mr. S. T. Powell of Baltimore, has been prepared with a view to help member countries of the United Nations to give particular attention to problems of 'Water of domestic, urban, agricultural and industrial uses including wider conservation through pollution abatement.

The introduction of this study contains a brief review of problems which arise from the demand for water by industry in competition with older and more traditional claims on water resources. Chapter 2 deals with the quantity aspects of industrial water use, whereas Chapter 3 takes up quality aspects. Industrial water costs are analysed in Chapter 4, and possible means, open to industrial plants and public authorities, of conserving limited water resources are discussed in Chapter 5. Chapter 6 presents the conclusions of the report and suggests action to be taken at national and international levels.

No. 3. **New sources of Energy and Economic Development.**

This study arose out of a resolution of the Economic and Social Council of the United Nations, requesting the Secretary General to prepare a report on the prospects for the practical utilisation of five new sources of energy, namely, solar energy, wind energy, geothermic energy, tidal energy and thermal energy of the seas. Its preparation has been helped by five specialists of international reputation.

The study can be divided into three main parts. The first of a general nature—a comparative study of the five new sources of energy in question. It reviews briefly the method which have been devised to control and utilise these sources for economic purposes (chapter 1) and evaluates their main characteristic features (chapter 2). Next, it examines the roles which they may play in the production of electric power (chapter 3) as well as the other uses for which important applications may be found (chapter 4). Finally, lines of action are suggested for development.

The second part of the report comprises five studies, one on each of the sources under review. These are extracts from the background papers of the specialists and are of somewhat technical nature. In selecting the extracts, the aim of the Secretariat has been to present a comprehensive picture of the development and utilization problems arising in the case of each energy source and, at the same time, to avoid inclusion of unduly technical computations or of literature readily available elsewhere and listed in the bibliography.

The bibliography, which was prepared by the United Nations Educational, Scientific and Cultural Organisation, constitutes the third part of the report. It has been compiled in such a way as to be of assistance to technicians as well as laymen interested in the fields in question. As an aid to the reader, short analytical annotations are given on many of the books and articles.

Water for Industry—Edited by Jack B. Graham and Meridith F. Burrill. Publication No. 45 of the American Association for the Advancement of Science, Washington D.C.

Man cannot live without water and of all the material resources, water probably is used in greater amounts and without which the industrial activities of modern era cannot thrive. Present-day is the age of industrial activities.

People of all parts of the globe are engaged in different types of economic activities. But in all sorts of activities the water is an indispensable product. The water is a gift of nature in some parts of the world where it is plenty, and similarly it is a curse in the arid and semi-arid areas. Thus the men have become water-gluttons where the water is abundant. But time may come when the demand for water would be heavy because of the rise of population. The time may also come when the consumption of water would require adequate planning. For this adequate planning the systematic organisation and proper collection of hydrologic data is necessary." The attainment of peak efficiency of water use on a national scale will not be easily or quickly realised, but not to strive for this husbanding of a vital resource would be as damaging to our national welbeing as for a person to

ignore a wound and slowly bleed to death". For this the American Association for the Advancement of Science deserves respect and admiration of hydrologists and scientists of the world.

The present volume consists of a series of thought-provoking papers contributed in a symposium by many welknown scientists. The interesting papers are Meridith F. Burrill's Geographic Distribution of Manufacturing, Powell and Knoedler's Water-supply and Waste Disposal Requirements for industry, and Russell Whitaker's Water in the Future. The mode of presentation of symposium papers in this book is a positive contribution of the editors of the publication.

It is an essential handbook to the Hydrologists, industrialists, geographers and the engineers related to the subject. We wish that this book will enhance its popularity in due course.

S. Sen

Proceedings of the Symposium on "Housing & Building Materials."

Vol. 1. Building Research and Design Practice.

Vol. 2. Status of Building Materials and Building Industry.

Edited by G. C. Mathur and published by National Building Organisation, Ministry of W.H.&S. New Delhi.

These two volumes have resulted from the proceeding of the Symposium on "Housing & Building Materials" held in March '56 at New Delhi on the occasion of the first meeting of the National Building Council. The purpose of the Symposium was to appraise the overall position of Building Design Techniques and Constructional Practices in India, and to bring eminent economists, sociologists, climatologists, architects and engineers together to find a solution for some pressing problems on building and housing.

Even a cursory reading of the publications indicate that these purposes have been fulfilled. Of course, we are promised still another volume to complete the set.

The contents of volume one include a review of Building Research in India, and a critique of existing Building Codes and Bye-laws. Then follows panel discussions on subjects such as, safety factors in design, new designs principles, structural problems, mud plaster and mud masonry, design values and climate and civic art.

In Vol. 2, we have general discussions on status of building materials and building industry in India, and on labour force for construction industry and draining programme for trade workers. Under panel discussions we have the following subject. Use of Light-weight Aggregate in Modern Building Construction; Problems of Testing and Manufacturing New Building Materials : Syllabus for Trade Training Programme ; Applied Finish : Durability and Colour Value of Paints ; and Use of Modern Construction Equipments.

It can easily be seen from the publication, that the symposium was highly successful and it must have been extremely helpful in fertilising our engineers and researchers with new ideas. We shall keenly look forward to the publication of the third volume.

D.V.C. in Prospect and Retrospect. Published by Damodar Valley Corporation, —Price. Rs. 3/-

Mr. Amal Home, Chief Information Officer of the Damodar Valley Corporation has done excellent work in producing this brief resume of the Damodar Valley Corporation, from its very inception. The illustrations, beginning with the devastation by the wayward river and concluding with the latest project developments, provide a full view of the transformation of the region from one of depression to that of prosperity. Printed on art paper, the book will be an interesting hand-book for tourists and students alike.

Bhagirath Pamphlets:

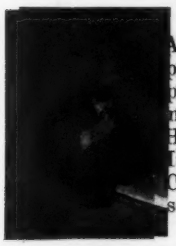
1. Major Water and Power Projects of India, Price 0.50 nP.
2. Population and Food Production, Price 0.25 nP.
3. Power for Industry, Price 0 25 nP.
4. Land Progress of Irrigation & Power, Price 0.25 nP.

These very interesting pamphlets published by the Publications Division of the Government of India, under the supervision of the *Bhagirath* staff, are very timely. They are well produced and factual, and should prove extremely useful to our legislators, teachers and students. In our opinion, such pamphlets in Indian languages would be of considerable educative value.

Building Foundation : Technical information series No. 5 put by the National Building Organisation.

This Technical pamphlet deals with two aspects of the problem, namely, site investigation and foundation in buildings. The first part is dealt with by Mr. Dinesh Mohan, and Mr. G.S. Jain. The second part has been dealt by Mr. Dinesh Mohan only.

Institute for Advanced Engineering and Technology for India suggested



Mr. E. J. Aaronson, the Finance Adviser (Export) of GEC, London paid a visit to India recently and put forward the suggestion that the creditworthiness of India in the eyes of the world. He made some useful suggestions regarding India's problems during his visit to Calcutta in June last. Following are some of the points made by him.

Supplier's credit is more important. There appears to be a misconception that this kind of assistance from Britain conflicts with your Government's present Import Policy. This is far from accurate for clearly, what in fact happens is that once the Union Government has established its proper priorities under the exhaustive criteria of "saving or earning foreign exchange" then, in respect of any project large or small where the Union Government never the less thinks that the scheme should go ahead it can by application of its own decision suggest to "phased foreign exchange terms" and it is here that the mechanism of what we in England call 'Supplier's Credits' begins to operate.

There is, of course, the not unimportant further point that in general, Capital Goods obtained under Supplier's Credit stand to be rather less expensive than those obtained within the framework of Government to Government Loans or Credits, since the former are usually a matter of commercial bargaining between Supplier and Customer, whereas, the latter are also influenced by all that is implied by Government to Government considerations as such has swinging accounts, and the vagaries of barter and compensation deals etc.

Even the contribution by the Soviet Union to the establishment of an Institute of Engineering Technology in India has by no means met your full requirements. Why then should you not consider suggesting to the Colombo Plan Organisation that as the ladders of Asia this might be the country where an equivalent Institute for advanced Engineering Technology (on the lines of the Massachusetts Institute of Technology) might be created under the Colombo Plan both for your internal purposes and perhaps later to assist you in your further functions as the ladders of progress in Asia.

You have put to have a system where under which your Customs Authorities are wont to say that imported goods have been invoiced at too low a value and, therefore, they tend to raise a subsequent Customs Duty. Surcharge. At the same time your Income Tax Authorities are sent to suggest that the same imported goods have been invoiced at too high a value and that therefore too much profit has been remitted from outside India.

What the greatest respect in the world do you not think that the time has come to re-examine this whole problem.

I appreciate that certainly for the time being this matter is of diminishing importance due to the essential contraction of imports but nevertheless it seems to me that it bears looking again.

This brings me back to Import Policy. There was a suggestion in the "Financial Times" of 29th of May that there might be a moratorium on all Imports for a period in order to conserve foreign exchange. Should this happen, do not let it die away you; but rather take it as a sign of the encouragement of those concerned who wish to show the world that India is determined to tackle her problems properly.

Our Contributors

Mr. W. Diesendorf graduated in 1929 from the Technical University of Vienna. He gained practical experience in high voltage and power engineering during a 10 years' association with a large electrical manufacturing company. During this time he was awarded a Doctorate in Technical Science from the above University.

In 1939 he joined the Sydney County Council Electricity Undertaking, Sydney, Australia, on whose staff he served for 11 years; during the latter portion of this period he was in charge of the System Planning Branch.

In 1950 he was transferred to the Snowy Mountains Hydro-Electric Authority, to take charge of the design of the Authority's electrical systems. In this position he was responsible for the investigations leading to the adoption of a 330 kV extra high voltage system in eastern Australia.

Mr. A. K. Bhaumick is Chief Electrical Engineer, Govt. of West Bengal and is a very senior electrical engineer in the country. He has contributed frequently in our journal, the last being in the West Bengal Symposium Volume VII, No. 9.

Prof. R. M. Advani graduated from the University of Bombay in 1944. After two years' experience in Bombay, P.W.D., he joined the staff at N.E.D. Engineering College, Karachi, where he continued till 1947. From 1948 to 1954, he was Lecturer in Civil Engineering at the University of Roorkee from where he came over to Jodhpur as Professor of Civil Engineering at the M.B.M. Engineering College, Jodhpur. He is engaged in Hydraulic Research work and has contributed so far over a dozen papers in various scientific and technical journals.

Alam Singh is an Honours Graduate of the University of Roorkee (1951), joined the staff at M.B.M. Engineering College, Jodhpur in 1953 as an Assistant Professor of Civil Engineering, after apprenticeship in the Irrigation Deptt., U. P. He has been for some time a research engineer at Centre Experimental de Recherches et d'Etudes du Batiment et des Travaux Publics, Paris. Apart from teaching Soil Mechanics & Foundation Engineering, he is engaged in research in Soil Mechanics and has got a number of published papers in leading technical journals in India to his credit.

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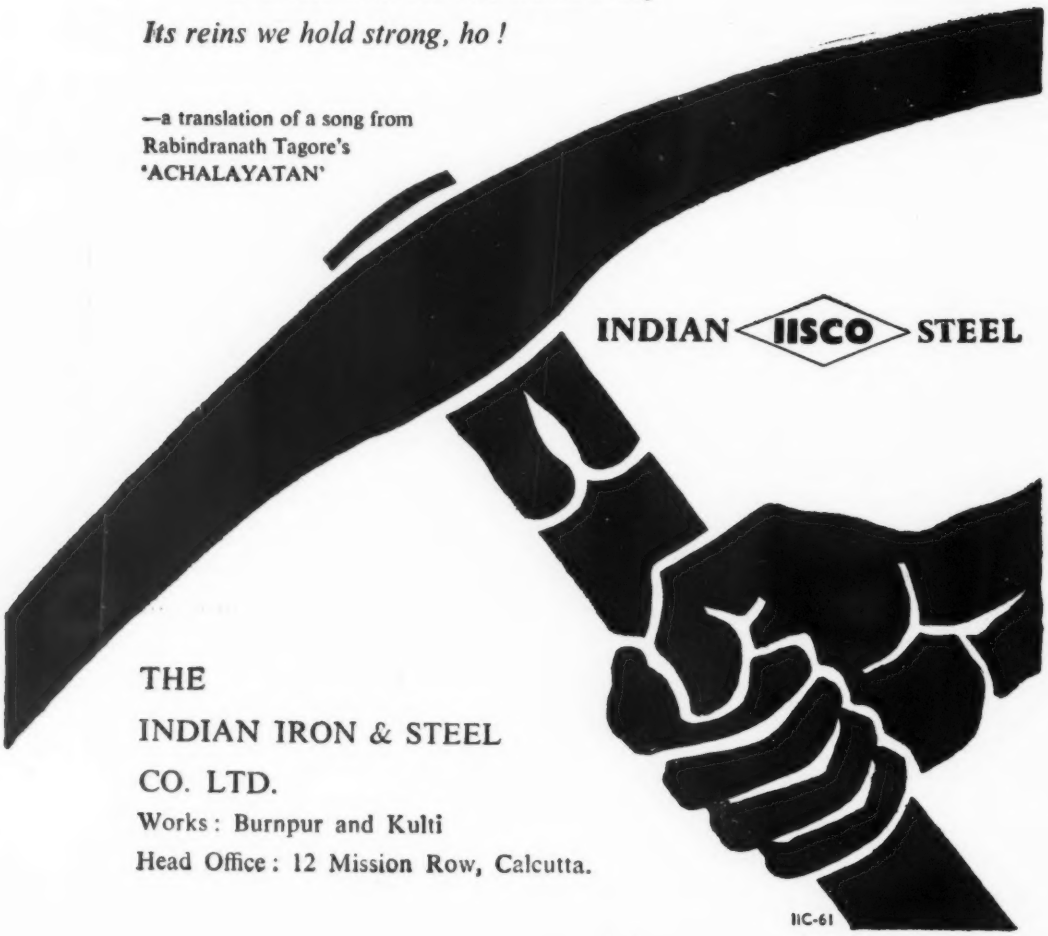
The hard iron lay dead in slumber deep
And we stirred it to life, ho !
In the dark depths of a million years it lay hid
And we stirred it to life, ho !
Tamed by our strong hands
It sings to the tune we call.
Its silence of long years have we broken, ho !
The dead doth stir with new life today
And rushes forth the wide world to conquer.
Fearless with our two hands today
Its reins we hold strong, ho !

—a translation of a song from
Rabindranath Tagore's
'ACHALAYATAN'



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